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1992 THESIS/~~DISSERTATION~~

Dual- Task Training Strategies and Aging

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AFIT/CI/CIA- 92-084

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BY

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B.S., U.S. Air Force Academy, 1991

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Arts in Psychology
in the Graduate College of the
University of Illinois at Urbana-Champaign, 1992

Urbana, Illinois

DUAL TASK TRAINING STRATEGIES AND AGING

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The goal of this study was to examine whether or not variable priority training could be effectively used by the older population to improve performance on dual-tasks and whether or not this training transfers to different levels of complexity as well as to different tasks. The objective of variable priority training is to maintain the context of the complete task, while manipulating emphasis on each of the subtasks as a function of online feedback and experimenter instructions. Twenty-four subjects (ages 61 to 79) participated in ten sessions. Random assignment to either variable priority training (VP) or fixed priority training (FP) did not produce a gender balance. That nonwithstanding, the results indicate that VP subjects had initial performance decrements related to the cost of learning a VP strategy. Once the strategy was mastered, however, VP subjects displayed learning where FP subjects did not. In transferring to new difficulty levels, no training advantages were evident. Variable priority training showed benefits in performance on novel tasks or novel additions to a learned task.

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Developing skills that improve dual-task performance is important to everyone, particularly the elderly. Strategies often guide our behavior as we perform complex dual-tasks (Gopher et al., 1989). A strategy provides an outline so we can "better cope with the set of subgoals of a task, the demands imposed by its different elements and the situations within which it is practiced" (p.149). The present study investigates the efficacy of a particular strategy developed to enhance performance in situations where humans must perform several complex tasks simultaneously. The specific question addressed here is whether or not this strategy, variable priority training, is suitable for an older population.

Dual-Task Performance and Aging

It is widely recognized that performance declines when two tasks are executed concurrently (see Braune and Wickens, 1986), but it is disputable whether or not this decline becomes worse with old age. Some of the literature maintains an age-related decrement exists for switching from single to dual-tasks (see McDowd, 1986; Talland, 1962; Hasher and Zacks, 1988; Madden, 1986; Park et al., 1989; Ponds et al., 1988; Broadbent and Heron, 1962). When Griew (1959) determined older subjects took longer to initiate a response than younger subjects, he interpreted it as an age-related decrement in the ability to monitor one movement while preparing for another. Alternatively, one could interpret it as a decline in a dual-task ability with age. In another study (Broadbent and Heron, 1962), older subjects were more burdened by the dual-task condition than younger subjects. A memory task paired with a distractor task (a "no-memory" search task) prompted many older subjects to neglect one of the two tasks. In contrast, younger subjects maintained a fair level of performance on both tasks.

In spite of these observations of an age-related decline in a time-sharing ability, there is increasing evidence to the contrary (see Somberg and Salthouse, 1982; Baron and Mattila, 1989; Wickens et al., 1987). For example, in a study by Baron and Mattila (1989), older subjects were consistently slower than younger subjects in absolute terms of a dual-task cost, however, they performed similarly in terms of relative dual-task costs. Following initial task training, subjects in both age groups had to produce correct responses within a given time limit, which became shorter as trials progressed. Under this time restriction, absolute response latencies diminished more for older subjects than younger subjects, resulting in smaller age differences. When the time restriction was removed, both age groups maintained the faster level of responding. Baron and Mattila argue that extended practice and training under time restrictions can alter older adults' responses and reduce age differences.

Somberg and Salthouse (1982) examined previous dual-task aging literature and found single-task performance had not been accounted for properly. In their study, although absolute decrements between dual- and single-task performance were greater for older subjects, no age difference was found in relative decrements. In contrast, Salthouse et al. (1984) have argued that greater relative decrements are found for the elderly. The contradiction between this and other studies is rooted in the complexity of the tasks. Somberg and Salthouse (1982) employed simple and repetitive tasks, while tasks used in other studies were more demanding and complex (see Salthouse et al., 1984; McDowd and Craik, 1988). Griew (1959) found even in a single task condition, complexity was more of an obstacle for older subjects than younger subjects. Moreover, studies which have included subjects from the ages of 18 to 80 have found significantly greater dual-task costs for the elderly, while equivalent costs were found for young and middle aged groups (Ponds et al., 1988; see also Talland, 1962).

Albeit with some opposition, the conclusion appears warranted that time-sharing complex tasks becomes increasingly difficult with age. However, even in the absence of age-related decline, improvement and preservation of dual-task performance and mental functioning is a worthwhile pursuit. To this end, efforts have primarily focused on three interventions: intelligence training, exercise, and variable priority/fixed priority training.

Strategies for Reducing Cognitive Decline During Aging

Intelligence training aims at providing subjects with skills to augment performance on tests of IQ. Scores on such tests may reflect overall cognitive proficiency (Stankov, 1988) and might therefore be expected to reflect cognitive processes involved in dual-task performance as well. Simple test taking skills, such as marking and filling in answers, can be practiced and improved, yet this does not impact the speed or performance on intelligence tests (Baltes and Lindenberger, 1988). Teaching problem solving skills was more effective (Baltes and Lindenberger 1988).

Problem solving skills involve identifying rules for solving inductive and figural relation problems and employing these rules. Baltes and Lindenberger (1988) found this was sufficient training for older subjects to improve performance on an IQ test.

Cognitive training techniques employed by Schaie and Willis (1988) enhanced one of two abilities, reasoning or spatial orientation. Training for the reasoning ability consisted of identifying pattern description rules used for solving problems and practice employing rules in problems similar to the intelligence tests and problems in other contexts. Training for the spatial orientation ability involved practice in mental rotation of objects. Specifically, the training strategies included practice on perceiving changes in angles, manual rotation of figures and drawings of familiar objects, subject-generation of names for abstract figures, and focusing on two or more features of the abstract figures during rotation. Older adults were classified as either "stable" or "declining" depending upon their performance on the Thurstone (1948) Primary Mental Ability Reasoning and Spatial Orientation over a fourteen year period. Although training was relatively brief, five 1 hour sessions, it was sufficient to reverse the decline in these two abilities (spatial orientation and reasoning) for many older adults (the "decliners"). In addition, training enhanced the performance of stable adults.

As a substitute for teaching cognitive skills, Baltes and Lindenberger (1988) recommend a longer time allowance for older subjects taking IQ tests. Given sufficient time, the elderly can exploit the cognitive skills they already possess such that their performance improves and may even reach the same level as those who were formally trained on cognitive skills.

The problem with the present level of intelligence training is its restricted range of applicability. Aimed at increasing scores on intelligence tests, cognitive training techniques bypass the broader aspects of cognition. Exercise has been pursued as a more general means to preserve and improve cognitive abilities, and acute exercise may have benefits specific to dual-task processing (Hawkins et al., 1992).

The literature suggests that healthy, elderly adults can benefit from a physical exercise program. Sherwood and Selder (1979) found cognitive functioning and reaction times remained stable across several age groups of runners. Hawkins et al. (1992) examined the single and divided attention performance of elderly adults before and after a ten week aquatic exercise regimen. Single-task performance increased equally for both the exercise and control groups (e.g. the control group did not participate in the exercise program). Dual-task performance, in contrast, was significantly better only for the exercisers.

In another relatively short term study (four months), Dustman et al. (1984) found previously sedentary adults (ages 55-70) improved performance on several neuropsychological tasks (e.g. Critical Flicker Fusion Threshold, Digit Symbol, Dots Estimation, simple RT, and Stroop tasks) as a function of exercise. Aerobic exercisers improved in all but two of the tested areas (Culture Fair IQ and Digit Span). The non-aerobic exercisers and control group improved in only one area each (Dots Estimation and Culture Fair IQ, respectively). Comparing the exercisers with the non-exercisers, Dustman et al. found a positive relation between exercise and cognitive improvement.

Spirduso (1975) examined reaction times and movement times of older and younger racquetsportsmen. Active men in general responded more quickly than their nonactive counterparts. In fact, active older men were faster than nonactive younger men. Since racquetsports require quick movements, active men who excel in these sports may have had a predisposition to move quickly. A follow-up study, (Spirduso and Clifford, 1978), corrected this possible confounding by including an additional activity level--running. The earlier findings were replicated. Sedentary men, young and old alike, reacted slower than active men, regardless of their chosen activity.

Other studies have also shown benefits for leading a physically active life (see Sherwood and Selder, 1979). In spite of these encouraging assertions, exercise is not always a viable option. An alternative that has no physical pre-requisites, yet may apply to a range of cognitive abilities is variable priority training. The overall aim of variable priority training is to improve subjects' control over their attention resources, such that their performance under dual-task conditions is improved (Brickner and Gopher, 1981). The assumption is that subjects can voluntarily control the amount of resources allocated to a particular task (Spitz, 1988; see also Keele and Hawkins, 1982; North and Gopher, 1976).

In variable priority training, a strategy guides subjects' allocation of resources to each of the competing tasks in a dual-task situation. The allocation of resources to a particular task (or task priority) varies at different times throughout the training as directed by feedback and experimenter instructions. The whole task ensemble is performed while priority on the subtasks is manipulated.

Gopher, Weil and Siegel (1989) utilized a very complex computer game, Space Fortress, to investigate voluntary control of resource allocation and task priority. Space Fortress is a dynamic videogame in an aviation environment. The ultimate goal is to destroy the fortress. A player must operate the space ship, fire missiles, and avoid land mines in order to achieve this goal. Gopher et al. maintained the context of the complete task (destroying the fortress), while manipulating emphasis on the subtasks (controlling space ship and avoiding land mines). Subjects were divided into four groups: (1) a control group that received no special training, (2) an emphasis group that placed more emphasis on one of the component tasks, ship control, (3) a group that placed more emphasis on the other component task of mine handling, and (4) a dual emphasis group that alternated emphasis between ship control and mine handling. The dual task emphasis manipulation appeared to be the most successful training tool. The dual emphasis group learned faster and in general performed better than the other three training groups, even after the priority manipulation had been removed. Subjects receiving only a single task emphasis manipulation were still better off than those who had none.

In a study undertaken by Brickner and Gopher (1981), subjects trained to perform a tracking/letter-typing dual-task combination under variable priority conditions could voluntarily control the emphasis placed on each task and were able to counteract changes in difficulty and changes in the task combination (transfer to tracking/digit classification or letter-typing/digit classification). In their study, subjects (ages 19-25) were grouped in three ways: variable priority with on-line performance feedback (VP), equal priority with verbal instruction (no bargraphs, NB), and equal priority with on-line feedback (EP). There were no differences in single task performance between the three groups at the training onset. As training progressed, the variable priority group learned quicker; they had steeper learning slopes than the other two groups. Once the training phase had concluded, the advantage of variable priority training remained. In contrast to the other two groups, VP performance remained stable in the face of difficulty and task changes, suggesting that subjects in this group were better able to cope with these changes. In addition, the EP and NB groups surprisingly never achieved the same performance level as the VP group, except when the latter placed the lowest priority on either task. In other words, the only time that VP training did not have a clear advantage was when they performed a task at the lowest level of priority.

On-line feedback indicated the desired level of performance, as determined by each subject's average performance level in single-task performance. This aided performance in the tracking task although not in the letter-typing task, and only in dual-task conditions. On-line feedback has been successfully used in other studies (see Gopher et al., 1989; North and Gopher, 1976).

Similar to the Brickner and Gopher (1981) study, the experiment described below compares variable priority training to fixed priority training. The aim is to assess whether or not the variable priority training could be effectively used by the older population to improve performance on dual-tasks and whether or not this training transfers to different levels of complexity as well as to different tasks. This study provides adequate practice on each of the single-tasks before beginning variable priority or fixed priority training on the dual-task configuration. During dual-task training, on-line feedback is provided so that subjects can continuously monitor their performance (as in the Brickner and Gopher study). Finally, complexity is manipulated within the original task on which subjects were trained, and within a novel task.

Method

Subjects

Twenty-four subjects (ages 61-79), responding to a newspaper advertisement were paid five dollars an hour to participate in the study. Additional parking fees were provided as needed. Twelve of the subjects (1 male) were randomly assigned to the fixed priority training group (FP) and the other twelve subjects (5 males) were assigned to the variable priority training group (VP). All of the subjects had at least 20/40 corrected vision and passed the Ishihara (1989) color blindness test. All subjects reported being in good health and free of any medication that may potentially cause deficits in performance (refer to Table 1 for a summary of demographic information).

Apparatus

Dell 386 SX computers with VGA color monitors were used to present the tasks in individual subject-rooms. Subjects were seated 60 centimeters from the screen and were allowed to adjust the lighting and seat height as they desired. (Refer to Figures 1 and 2 for the layout of each of the task displays).

Tasks

The experiment consisted of four tasks, each with three levels of difficulty. Subjects were trained using monitoring and letter-arithmetic tasks, and then transferred to scheduling and running-memory tasks.

Monitoring Task. In the first task subjects monitored six constantly changing gauges, each with a magenta cursor moving clockwise. Each gauge was consecutively numbered from 1 to 12, starting with the number one at the six o'clock position (see Figure 1). In addition, each third of a gauge was divided into colored segments (green, yellow or red). Red denoted the critical region and covered the last third of a gauge (numbers 9 through 12). Subjects were instructed to monitor each gauge and to reset its cursor once it was in the critical red section (see Appendix A for task instructions and for the keypads that were used to monitor and reset the corresponding gauges).

All gauges were displayed concurrently; however, the cursors remained concealed until subjects pressed the appropriate key. In addition, each cursor appeared independently so that no two cursors could be viewed at the same time. A magenta cursor appeared for 1500 milliseconds, each time a gauge was monitored. The cursor reset automatically after 7500 milliseconds in the red area if no response was made. Subjects received feedback that a cursor had been reset by its appearance (2000 msec) at the bottom of the gauge. It was blue if the computer reset it; magenta, if it was reset by the subject. When a cursor was reset before it was in the red area or it reset automatically, it was scored as an error.

Cursor movement around the gauge was driven by three events: base speed, jitter and transient movement. The slowest cursor took the longest to reach the critical region. In addition, the initial starting point of each cursor was randomized. Jitter is the amount of "jumping" in the cursor's behavior. The jitter of a cursor varied with respect to its magnitude and frequency. A higher magnitude made the cursor movement larger. The jumps could be either forward or backward, but the cursor moved in a clockwise direction to the critical gauge region. The frequency of the jitter determined how often the cursor jumped. Finally, transient movement increased the randomness of the cursor's movement by producing occasional jumps supplementary to the jumps produced by the jitter.

The three kinds of cursor movement were varied to create three difficulty levels. In the low difficulty condition, cursors in the same row of gauges had the same base speed and jitter, and there were no transients. In the intermediate difficulty condition, each column of cursors moved at the same speed, as contrasted with the low difficulty condition. The jitter had greater magnitude and frequency than the low difficulty condition and the number of transients went up to two. In the most difficult condition, each cursor had a different base speed. The jitter had the greatest frequency and magnitude. This condition also had the greatest number of transients which made its movement the most difficult to predict. Level of difficulty was validated through a four subject pilot study.

<u>Letter-Arithmetic Task</u>. In the letter-arithmetic task, arithmetic equations of numbers and letters had to be solved with

the correct letter as quickly as possible (as in a study by Logan and Klapp, 1991). For example, the equation K - 2 = ? would be answered with the letter I (refer to Appendix B for additional details).

The numbers used in the equation were randomly chosen, ranging from 1 to 3. Letters were also randomly selected, ranging from A to M for half of the subjects and from N to Z for the rest of the subjects (the transfer task assigned the opposite half of the alphabet to subjects). Subjects always responded with the left hand, so that the right hand would be free for the gauge task in the dual task condition. Between trials, the word correct or incorrect was displayed for one second to give performance feedback.

The task was self-paced in all three difficulty conditions. In the easiest difficulty condition, subjects simply solved each equation. At the intermediate and high difficulty levels, the objective was to mentally solve each equation, then make a comparison. Comparison trials always had white letters, non-comparison trials red letters. An arrow pointing up or down appeared on all comparison trials, indicating that the desired response for that trial would be the higher or lower of the two letters. The higher letters were closer to Z, the lower letters were closer to A. In the intermediate condition, subjects answered the first equation (red) and were instructed to remember that letter response (if it was correct). In order to correctly respond on the comparison trial (white), subjects had to recall the letter response made on the previous trial and compare that with the answer to the currently displayed equation. On all subsequent trials, subjects had to compare the response of the immediately preceding trial to the answer of the currently displayed equation. For example, if the answer to the first equation was F and the answer to the second equation was G, then the comparison would be between F and G. An arrow pointing down would indicate the lower of the two responses, therefore, the correct response would be F. The last response made, F, must be remembered for comparison in the next trial. Any incorrect response was followed by a non-comparison trial.

In the most difficult version of the letter-arithmetic task, the responses were analogous to those in the intermediate version, however the letters to be compared differed. In the most difficult condition, subjects compared the answer of the preceding equation with the answer of the current equation (in contrast to the intermediate condition where one compares the response of the previous equation with the answer of the current one). The answer to the preceding equation was not necessarily the higher or lower response, sometimes subjects were required to respond with one letter but remember another for the next comparison. For example, the answer to the first equation could be C, and the answer to the second equation could be D. The arrow may indicate the lower of the two letters. The subject then responds with C, but must remember D for comparison with the next equation. For the third equation, the answer may be H, with an arrow pointing down. The correct response would be D, however, the letter H must be remembered in order to compare it with the answer to the fourth equation, and so on (see Appendix B for more details).

Scheduling Task. This task is similar to the dynamic computer-monitoring task employed by Fuld, Liu and Wickens (1987) in that the overall goal of the task is to serially assign incoming stimuli to a target line. In this version, subjects assigned colored boxes that appeared in the upper left corner of the screen to one of four horizontal "assembly lines", depending on which line had the smallest area of cumulative boxes (see Appendix C for additional details). Boxes were moved off assembly lines (and off the screen) at different rates. Larger boxes moved slower than smaller boxes. Subjects were instructed to use their right hand to manually assign red boxes to the "assembly line" with the least cumulative area of boxes. They had 7 seconds to assign a red box to a line before it was automatically done by the computer, which counted as an error. As in the Fuld et al. (1987) study, boxes could be either manually or automatically assigned. Twenty-five percent of all boxes were to be assigned by the subject and were red in color. Boxes to be assigned by the computer comprised the remaining seventy-five percent (blue) and appeared in the upper left corner for 2 seconds. If the computer assigned a box, subjects had to verify that the correct line was chosen within 5 seconds. Once the assignment was verified, the color of the box changed to yellow, regardless of the accuracy of the subject's choice. In contrast to the Fuld et al. (1987) study, subjects could predetermine the box assignment, however, once an assignment was made, it could not be altered. Also, subjects were not provided with immediate feedback on the accuracy of any given box assignment but with online feedback pertaining to the level of desired performance.

For all difficulty levels, the length of the boxes was random (20-80 pixels). Difficulty was manipulated by varying box heights. In the least difficult version of the task, boxes were equal in height. There were three different box heights for the intermediate difficulty version of the task and five different heights for the most difficult condition. In all versions, the correct receiving line was the one which had the least area of boxes (shortest in height and width). Level of difficulty was validated through a four subject pilot study.

Running-Memory Task. Letter-number pairs, such as A = 2, appeared on the screen in a random order and subjects were required to keep a running memory of the most recent value assigned to each letter. After four to seven presentations, a red letter-number pair appeared. Subjects were to indicate whether the value currently displayed was the most recent one assigned to that letter. Half of the subjects used the "<" key for a "yes" response and ">" for "no"; while the other half used the opposite key assignment. Numbers varied randomly from 1 to 8, while letters varied from A to C, A to D, or A to E, for the low, medium and high difficulty versions of the task (see Appendix D for additional details).

In all of the tasks described above, subjects were encouraged to respond as quickly and as accurately as possible.

Procedure

The three phases of this study were preliminary testing/task familiarization, training and transfer. Subjects participated in ten sessions, each lasting approximately one and a half hours (see Table 2 for a summary of the session itineraries). The procedure is essentially the same as that employed by Brickner and Gopher (1981).

Preliminary Testing/Task Familiarization. A series of paper and pencil tests were administered at the beginning of the first session. Examiners administered the Kaufman Brief Intelligence Test (K-Bit), tests of visual acuity and color blindness (Ishihara's Test for Colour-Blindness, 1989), a health questionnaire, and the Wechsler Adult Intelligence Scale (1981) Digit Span forward and backward (as a measure of recent memory). Demographic data was also gathered during the first session.

The monitoring (or gauge) task and letter-arithmetic task were practiced separately in each of the first two sessions. Order of presentation of the two tasks were counterbalanced across subjects. Written as well as verbal instruction was provided to insure the tasks were well understood. Each task in the first session was performed at the intermediate difficulty level, with one 90 second demonstration block and five 5 minute practice blocks. Feedback was provided at the end of each block, so subjects could observe their improvement in mean reaction time and accuracy. These five 5 minute practice blocks were repeated in the second session to ensure that subjects understood the task. Only the data from the second session was used in the analysis.

Subjects started the third session with four 5 minute blocks of each single task at the intermediate level (half started with the letter-arithmetic task, half started with the gauge task). Because the letter-arithmetic task was self-paced, the number of events per block depended on how quickly subjects responded during each five minute interval. Following single task practice, all subjects performed six 5 minute blocks of both tasks simultaneously (see Figure 1 for an illustration of the dual task display). The dual task feedback showed general improvements in task performance.

Training. Subjects were randomly divided into two training groups, fixed priority (FP) and variable priority (VP) training, prior to session 4. Fixed priority training subjects were instructed to perform equally well on both tasks in the dual-task condition. Before each block, VP training subjects were instructed how much priority each of the tasks should receive. Further written instruction which articulated the meaning of each priority manipulation was furnished. The five different priority combinations in the variable priority training were: 20 percent priority on one task versus 80 on the other, 35 versus 65, 50 versus 50, and vice versa. Assignment to the priority groups was for sessions 4, 5 and 6 only.

Subjects in both FP and VP training groups performed the dual tasks at the intermediate difficulty level in sessions 4 through 6. Ten 5 minute blocks of the dual task were presented at the beginning of each session; the number of trials per block depended upon the speed of the subjects. Both FP and VP training groups were given continuous feedback indicators during each block which indicated the priorities that they were to assign to each task as determined by each subject's average performance in the single-task condition. The fixed priority training group feedback always indicated a 50/50 emphasis during trials, and the feedback for variable priority training indicated one of the five possible difficulty combinations (i.e. 20/80, 35/65, 50/50, 65/35 or 80/20). At the end of each session, the gauge and letter-arithmetic tasks were performed alone in order to assess learning.

Transfer. Starting with the seventh session, the dual-task configuration was performed at three difficulty levels: high, medium and low difficulty. A high difficulty gauge task was paired with a low difficulty letter-arithmetic task, medium difficulty was paired with medium, and low difficulty was paired with high. The presentation of four 5 minute blocks for each dual task combination was randomly ordered, with no feedback bargraphs in either priority training group during a block (see Figure 2 for an illustration of the dual task display). Between every block, subjects were given instructions for the following difficulty combination and were directed to protect their performance (i.e. maintain single-task levels of performance) at each difficulty level. At the end of each session, subjects performed one 5 minute single-task block of each difficulty level (low, medium, and high) for the gauge and letter-arithmetic tasks separately.

Session 8 followed the same procedure as the previous one, except that subjects in the letter-arithmetic task who started with the first half of the alphabet switched to the latter half, and vice versa.

Finally, during the last two sessions (sessions 9 and 10) subjects transferred to two new tasks: the running-memory and scheduling tasks. Subjects practiced the three difficulty levels (low, medium and high) of each task separately, one 5 minute block of each difficulty level per session. The dual task portion paired a high difficulty task with a low difficulty task, a low difficulty task with a high difficulty task and a medium difficulty task with a medium difficulty task in four 5 minute blocks for each difficulty combination. Instructions were provided before each 5 minute block. Subjects received reaction time and accuracy feedback in the single- and dual-task.

Results

The results will be discussed in the following order: initial performance levels in single- and dual-tasks before priority training, performance levels during training, and performance levels in the two transfer conditions after training concluded. The differing variables and statistical tests employed for all analyses will be discussed in their respective sections.

Preliminary Distinctions

Sessions one through three were intended to familiarize subjects with the tasks. Session one also included the paper and pencil testing that was described above (in the Subject section of Method). The paper and pencil data were analyzed to discover any differences between training groups, however the only significant difference occurred in gender ($p<.01$). The VP training group consisted of 3 females and 5 males, while the FP training group had 11 females and only 1 male. Intellectually, subjects were well matched; the average standard composite scores on the Kaufman Brief Intelligence Test (K-Bit) were not significantly different (refer to Table 1 for mean demographic and paper and pencil data). The performance data from session one was eliminated from the analyses since it served more as a demonstration session than a practice one.

Three subjects from the variable priority training group were dropped from the analyses. A visual analysis of each individual's Performance Operating Characteristic (POC) revealed these three subjects were not shifting their task emphasis as instructed. A Kruskal-Wallis test was then performed with a conservative alpha level of 0.25. The results of this test confirmed these subjects' performances differed significantly in at least one measure on each task (i.e. gauge reaction time, letter reaction time, gauge accuracy or letter accuracy). A fourth subject was dropped because of extremely high variance and unusually poor accuracy.

T-tests were performed to compare FP and VP performance during sessions 2 and 3. Performance was compared on the following variables in the single- and dual-task versions of the monitoring task: mean and median reaction times, number of correct responses, standard deviation of correct response reaction times, the percent of cursors hit (correctly reset once in the red section), the percent of cursors missed (cursors automatically reset), and the percent of false alarms (cursors reset before the red section; refer to Tables 3-6 for a summary of the results). Although there were several significant performance differences between FP and VP training groups in session 2 (e.g. as indicated by asterisks in the tables) these differences were absent in session 3.

Type of training and session were the only factors examined in single- and dual-task performance of the letter-arithmetic task. The variables contrasted in the t-tests were mean and median reaction times on trials answered correctly, the standard deviation of correct responses' reaction times, the number of correct responses, and the percentage of correct responses. In all of these performance measures, both training groups performed equivalently.

Performance Results During Priority Training

Variable and fixed priority training was conducted in sessions four through six. Each task was analyzed independently in both single- and dual-task conditions. For the monitoring task, a mixed ANOVA design was used to analyze the following performance data: mean and median reaction times, the hit rate (cursors correctly reset once in the red section), the miss rate (percent of cursors automatically reset), and the percent of false alarms (cursors reset before the red section). Factors analyzed in the single task version of the monitoring task were session (4, 5, and 6) and training (FP and VP); no main effects were found (refer for Table 7 for mean performance results). Dual-task effects will be discussed later.

A mixed ANOVA design was also employed for the letter arithmetic task. The dependent variables were mean reaction time, median reaction time, and accuracy; the only factors were session and training. The single-task analysis showed a significant interaction between session and training in median reaction time ($F(2,35)=4.55$, $p<.0176$). Subjects trained in fixed priority strategies had an initial speed advantage; however, they did not demonstrate learning over time (see Table 8). The performance of the variable priority training group improved with practice (refer to Figure 3 for a graphical depiction).

The dual-task analysis in sessions 4, 5, and 6 was conducted in two parts. The first part took data from both FP and VP training groups together and compared the two 50/50 emphasis blocks for the VP training group (which occurred in a random order for each subject) with two 50/50 blocks from the FP training group corresponding to the same blocks of practice (refer to Tables 9 and 10). The second part analyzed data from each training group separately and will be discussed later.

In the first analysis, factors were session (4, 5, and 6) and training type (VP or FP). In the letter-arithmetic task, a session by training interaction was significant for mean reaction time ($F(2,36)=3.67$, $p<.0355$, see Table 10 and Figure 4), but not for median reaction time. The VP subjects increased their response speed with practice while the FP subjects' response speed did not change with practice. When the gauge task was performed in the dual-task setting, the VP group performed almost 350 milliseconds slower than the FP group in reaction time ($F(1,18)=6.05$, $p<.0242$, refer to Table 9).

The second analysis was then performed for each dual-task training group across all blocks for each task. Session (4, 5, and 6) was the only factor analyzed in the FP training group. The FP subjects displayed a practice effect in the gauge task, but not the letter-arithmetic task (see Tables 11 and 12). Practice considerably lowered their false alarm rate or rate of prematurely resetting cursors in the gauge task ($F(2,350)=4.26$, $p<.0149$). No other measures (hit rate, reaction times) showed significant improvement.

In the analysis of the VP performance, factors were priority (20, 35, 50, 65 and 80) and session. The VP training group displayed practice effects in the gauge task (see Table 13). Accuracy increased with sessions in terms of more hits and fewer misses ($F(2,226)=4.54$, $p<.0013$ and $F(2,226)=3.16$, $p<.0052$, respectively). Although there was a trend for faster response times in the gauge and letter-arithmetic tasks across session, this trend was not significant (Tables 11 and 14).

The VP training group was additionally examined for priority effects. The aim was to insure these subjects shifted their emphasis on each task (recall that four subjects were dropped because they could not shift their emphasis correctly). Priority effects were present in both gauge and letter tasks and most of the dependent variables (see Tables 15 and 16 for a summary of results). In addition, the correct emphasis trade-off was often observed for these variables. For example, the highest miss rate occurred when 20 percent was the desired emphasis, the next highest miss rate occurred with a 35 percent emphasis, and so on.

Priority shifts can also be examined pictorially. A Performance Operating Characteristic (POC) plots subjects' performance of two tasks concurrently, such that trade-offs between tasks can be observed (refer to Figure 5). The single-task performance data is plotted on each axis to serve as a maximum performance reference point.

The POC graphs illustrate that variable priority training subjects are trading-off accuracy and reaction time as a function of instructions. The gauge task reaction time/letter-arithmetic task reaction time plot shows little change in gauge reaction time as a function of shifting priorities. In contrast, the reaction time of the letter task varies quite substantially. Accuracy of the two tasks plotted against each other display a shift in gauge accuracy (percent hits) as function of priority, but little change in letter-arithmetic accuracy (percent correct). The cluster of points in the third plot (gauge reaction time/letter accuracy) suggests maintained performance in letter accuracy and gauge reaction time regardless of online feedback and experimenter instructions. The best depiction of a performance trade-off due to priority manipulation is a plot of letter reaction time against gauge accuracy. This POC plot shows a distinct trade-off between the two tasks. It also shows the 50/50 allocation point slightly bulging out from a line drawn between allocation points (this bulge is more evident in POCs for individual subjects). Since the best dual task performance is nearest the top right corner of the POC, subjects appear to be most efficient with a 50/50 allocation policy. In summary, priority effects in the letter arithmetic task were most prominent in the speed performance, while accuracy showed the effects of manipulating emphasis in the gauge task.

Effects of Training in Transfer Conditions

In sessions seven and eight, the training manipulation was removed. New difficulty levels were presented in session seven, while session eight presented these difficulty levels as well as the opposite half of the alphabet in the letter-arithmetic task. Sessions 9 and 10 present two novel tasks: running-memory and scheduling. Transfer results in the single-task version of each task will be followed by the results in the dual-task version of each task for sessions 7-10.

A mixed ANOVA design was used to analyze training group (FP and VP) and difficulty level (low, intermediate, and high) effects in both the gauge and letter-arithmetic tasks. Accuracy and response speed were dependent variables in both tasks.

In session seven, no significant effects were obtained in the single task version of the gauge task (Table 17). When the letter-arithmetic task was performed as a single task, level of difficulty had a significant effect on accuracy and RT ($F(2,36)=9.55$, $p<.0005$ and $F(2,36)=38.67$, $p<.0001$; refer to Table 18). The highest difficulty condition had the longest median RT, as well as the lowest hit rate (accuracy). There were no significant differences between the variable priority and fixed priority training groups in this session.

In the dual-task conditions of session seven, difficulty main effects ($F(2,36)=12.93$, $p<.0001$, and $F(2,36)=4.64$, $p<.0161$) in the gauge task signified a difference in terms of hits and misses between the easiest and the two harder versions (see Table 19). Surprisingly, the intermediate and highest levels of difficulty in gauges had the highest hit rates and the lowest miss rates. A difficulty main effect ($F(2,36)=38.20$, $p<.0001$) for percent hits was present in the dual task letter-arithmetic task (Table 20).

A main effect for difficulty ($F(2,36)=3.32$, $p<.05$) was obtained for miss rate in session 8 of the single condition of the gauge task (Table 21). This showed the intermediate difficulty level had the lowest rate of misses. There was also a significant effect for difficulty in median reaction time and hit rate for the letter task ($F(2,36)=33.80$, $p<.0001$, and $F(2,36)=20.31$, $p<.0001$, respectively; see Table 22). The trend is such that the easiest versions showed better performance than the intermediate version which in turn showed better performance than hardest version.

A training by difficulty interaction was significant for median reaction time in the single task version of letter-arithmetic in session 8 ($F(2,36)=5.17$, $p<.0106$; see Figure 6). The VP subjects were faster than the FP subjects at the low and intermediate difficulty levels. The effect at the most difficult task level showed FP subjects were now equivalent to VP subjects. In the difficulty by training interaction for accuracy, the VP group was more accurate than the FP group at the highest level of difficulty, ($F(2,36)=3.43$, $p<.0432$; see Figure 7). Otherwise, accuracy was equivalent for the two training groups. In the dual-task versions, significant effects for difficulty were obtained for hits in both tasks and misses in only the gauge task (refer to Tables 23 and 24).

Sessions nine and ten were designed to examine the effects of training on performance in two novel tasks, running-memory and scheduling. A mixed ANOVA design was used to analyze both running-memory and scheduling tasks. The dependent variables in the running-memory task were accuracy and mean and median reaction times. In the scheduling task, the nature of a trial was considered an independent variable, while accuracy and response time measures were considered dependent variables. A trial could require a manual assignment of boxes or automatic assignment. The latter required subjects to verify the assignment was done correctly. The effects of practice, training and level of difficulty were analyzed. The effects examined in the running-memory task were practice, training, level of task difficulty and whether the probe in each trial was correct (requiring a confirmation by subjects) or not (requiring a negative response).

In the single-task condition of the running-memory task, main effects of session was significant for median reaction times ($F(1,18)=9.00$, $p<.0077$), showing that RT improved with practice (Table 25). An interaction of session by training for reaction time ($F(1,18)=4.00$, $p<.0608$) demonstrated an initial VP training advantage in session nine, but by session ten, FP subjects performed equivalently to VP subjects (see Figure 8). Running-memory accuracy showed an effect of difficulty, revealing a substantial cost in the two highest difficulty levels ($F(2,36)=5.76$, $p<.0067$). There was also a main effect ($F(1,18)=7.08$, $p<.0159$) for the correctness of the trial probe. Subjects were more accurate repudiating an incorrect probe than confirming a correct one.

There was a main effect of difficulty for RT and accuracy for the single-task version of the scheduling task (see Table 26-28). A main effect was also obtained of session on RT. Although accuracy did not improve as a function of practice, the variable priority group was significantly more accurate than the fixed priority training group on manually assigned boxes ($F(1,18)=4.38$, $p<.0508$). On correctly assigned automatic boxes, a marginally significant training by level of difficulty interaction was present for accuracy ($F(2,36)=2.50$, $p<.0966$). The VP performance at the easy level was ten percent better than FP performance. At the medium and hard levels, there was only a two percent difference in performance between training groups, with the VP's being less accurate. No significant effects were found for incorrectly assigned automatic boxes.

When performed in a dual-task setting, the running memory task showed substantial practice effects for RT (mean $F(1,18)=7.65$, $p<.0127$ and median $F(1,18)=9.60$, $p<.0062$). Accuracy decreased with increases in the task difficulty ($F(2,36)=10.21$, $p<.0003$; Table 29).

Two interesting results were found with regard to correctness of the probe trial. First, subjects' accuracy in confirming a true probe trial decreased with added difficulty, but remained the same in negating a false probe trial ($F(2,36)=4.83$, $p<.0138$; see Figure 9). Second, a three way interaction between training, difficulty and probe type was obtained for mean RT ($F(2,36)=3.99$, $p<.05$, refer to Figure 10 for a graphical depiction). This shows subjects in both training groups responding in a similar fashion when the probe was incorrect, but the VP training group was approximately 700 milliseconds slower. On correct probe trials, the FP reaction times were slowest at the high level of difficulty, fastest at the intermediate difficulty level, and in between at the low difficulty level. The VP reaction times were fastest at the low level of difficulty, slowest at the medium level of difficulty, and moderate at the high level of difficulty.

In the dual-task version of scheduling, difficulty exerted a significant main effect on all dependent measures (see Tables 30-32). The intermediate difficulty was often the slowest, but it was not significantly slower than the highest difficulty level. An interaction between training and difficulty ($F(2,36)=3.42$, $p<.05$) demonstrated that the VP training group was slower manually assigning boxes at the two highest difficulty levels (Figure 11). The two training groups performed equivalently at the lowest difficulty level. The FP performance remained fairly stable across difficulty conditions, while the VP performance declined.

Discussion

The primary goal in the study was to determine the relative merits of variable priority and fixed priority training for enhancing the dual-task performance of older individuals. It is important to note, that with regard to the issue of training strategies, the results reported here are considered to be preliminary given the small number of subjects in each of the experimental groups. It was also the case that the number of males and females as well as the average age of the subjects differed in the two groups. These factors will be balanced across groups in the continuation of this study. These cautions nonwithstanding the present results provide important new information concerning the efficacy of training strategies for the elderly.

Training

In the training sessions (sessions 4-6), one would expect both VP and FP training groups to exhibit some form of learning on the tasks. From the single-task data of the monitoring task, neither training group demonstrated a learning effect. When performed with the letter-arithmetic task, however, VP subjects were significantly slower than the FP subjects. This may be interpreted as a greater concurrence cost for the VP subjects, however, results from the letter-arithmetic task shed more light on this finding. A session by training interaction appeared in both single- and dual-task versions of the letter-arithmetic task (Figures 3 and 4). Variable priority training led to a continuous improvement in performance across sessions while FP did not. Since the interaction was present in the single-task condition, greater VP cost of concurrence can be ruled out. Gopher et al. (1989) stated that a variable priority training strategy was an additional source of complexity. Add to this the fact that the elderly experience substantial performance decrements with added complexity (see Griew, 1959; Lorsbach &

Simpson, 1988; McDowd & Craik, 1988), and it is not at all surprising that the VP subjects were initially slower. Once these subjects were proficient at the variable priority training strategy, they were able to apply it to their performance. Fixed priority subjects never had this additional load and were therefore faster in the early sessions.

Other studies have found that VP training enhanced the speed of subjects' learning (see Gopher et al., 1989; Brickner and Gopher, 1981). In the present study, only the VP subjects showed any significant learning in both the single- and dual-task conditions. The FP subjects did not show any systematic improvement in either speed or accuracy in the letter task or speed in the gauge task. However, the FP subjects did show an improvement in the number of false alarms across sessions in the gauge task.

As important as the learning exhibited in the training sessions is the ability of subjects in the VP group to shift task emphasis. Four of the subjects in VP training were not able to shift their emphasis between tasks (and were later omitted from analyses), despite all efforts to adequately instruct them. Several authors have had success getting subjects to manipulate task priorities using online bargraphs and verbal instruction (Gopher et al., 1989; North and Gopher, 1976). Thus, these means as well as written instructions were considered sufficient guidance for older subjects in this study. It is unlikely that subjects intentionally failed to vary their task emphasis.

Brickner and Gopher (1981) state that allocation policies cannot be controlled by the experimenter and sometimes not even by the subjects. That may be the case for these subjects.

Other subjects often commented on the difficulty of definitively allocating 80/20 percent of their resources versus allocating 65/35 percent. Specific values were not easily interpreted, thus subjects tended to group the two highest priority levels (80 and 65) and the two lowest ones (35 and 20). In other words, subjects often demonstrated an allocation strategy of "a lot" versus "a little" instead of 80 percent versus 20 percent emphasis. This was evident in both the POC graphs and the statistical results of priority effects.

The POC plots offered new perspectives on the statistical results (refer to Figure 5). Although speed and accuracy were equally stressed in the task instructions, it appears that subjects chose to emphasize accuracy in the letter-arithmetic task, and speed in the monitoring task. For example, in the letter-arithmetic task, subjects preferred to answer correctly, regardless of the time it took (a cost of speed in maintaining accuracy). Even when the task had to be performed simultaneously with the other task, subjects still attempted to answer correctly. Older adults may compensate for perceived slower response time with greater accuracy. In the gauge task, however, reaction times remained stable while accuracy shifted. Subjects were instructed to monitor six constantly changing gauges and when the task was performed alone, subjects could monitor all six gauges and reset most of the cursors. When the gauge task was performed in dual-task conditions, several subjects mentioned that not all of the gauges could be supervised, and they would therefore monitor only a few. Instead of ignoring each of the gauges to the same extent, most subjects preferred to monitor a few gauges as well as possible and ignore the remaining gauges, the effect of this strategy being that the failure to monitor some gauges would reduce accuracy (more misses) while it would not affect reaction time (no response time for those gauges, same response time for others).

The POC plots revealed efficiency differences across conditions. A cost of concurrence was expected and found. That is, all subjects experienced performance decrements in switching from the single- to the dual-task condition. Also, subjects may have performed tasks more efficiently using a 50/50 priority strategy, since it may have required less effort than other policies.

Transfer

The purpose of the transfer phase was to assess the extent to which priority training (either fixed or variable) would be useful in other contexts (different tasks or levels of difficulty). Dustman et al. (1992) found that skill developed while playing a generic off-the-shelf videogame transferred to performance on simple and choice RT tasks. Since the "game" used in this study was specifically structured to measure transfer effects (whereas as the other was built for entertainment purposes), more benefits could perhaps be expected. On the other hand, smaller benefits would be expected since Dustman et al. compared a game condition to no training and this study compares two training conditions (i.e. a no-training control group was omitted).

In the first transfer session in which subjects performed the two tasks at different difficulty levels (session 7), there were no main effects in the single-tasks other than the effect of difficulty in the letter-arithmetic task. Training had no effects on performance.

In the dual-task condition of the monitoring task in session 7, the intermediate and highest levels of difficulty had the highest hit rates and the lowest miss rates. In the dual-task condition of the letter-arithmetic task, a difficulty main effect for percent hits was present. These two findings suggest that subjects ignored the gauges when the most difficult letter-arithmetic task was paired with the easiest version of the gauge task. Possibly the letter-arithmetic task was too demanding to allow better performance on the easy version of the gauge task (recall that no differences e ted for level of difficulty in the gauge task for the single task version). Tsang and Wickens (1988) found that subjects (ages 19-30) could protect performance when performing tasks of different difficulties if resources originally allocated to a secondary task were transferred to a primary task. It could be that subjects in this study were doing that of their own volition, regardless of training. If the most difficult version of the letter task were too taxing, then it would not be unreasonable to assume subjects reallocated all of their resources for the secondary (gauge) task to the primary (letter) task. It would have to be assumed that subjects assigned the letter or most difficult task to be the primary task. Unlike the Tsang and Wickens study, however, training had no effect.

In session eight, the letter-arithmetic task was performed with the unpracticed half of the alphabet. Performance in the single-task version of the letter task showed a significant effect for difficulty in reaction times and hit rate, further establishing a distinction between each level of difficulty.

A training by difficulty interaction appeared in the single-task performance of the letter-arithmetic task in session 8 (Figures 6 and 7). The subjects in VP training performed nearly one second faster than FP training subjects at the low and intermediate levels of difficulty. At the highest level of difficulty, however, VP subjects were essentially equivalent to FP subjects. There is an explanation for why VP subjects are faster in letter performance, but not more accurate. Referring back to the POC plots, priority effects strongly influenced reaction times in the letter task. Since VP training was most effective in this measure, VP training effects might be expected to carry over to the same measure in other sessions.

Letter-arithmetic accuracy measures reveal why different difficulty levels show different training advantages. Levels of accuracy were equivalent for the VP and FP groups at the lowest difficulty level. As difficulties increased, the FP group showed a consistent decline in accuracy with added complexity. In contrast, the VP group maintained the same level of accuracy for the intermediate and high difficulty levels. It may be that subjects at this high level of difficulty are no longer able to utilize the VP training to improve task RT performance (where it was most beneficial in training), but use it instead to maintain accuracy performance because the demands of the task are so great.

In general, performance in both tasks was affected by the manipulations of difficulty. Also, a new version of the letter task showed a VP training advantage. At the low and intermediate levels of complexity, VP training was more beneficial to performance; it enhanced subjects' speed more than FP training. At the high level of complexity, VP training enhanced subjects' accuracy performance. If a small change in the letter task shows such advantages for variable priority training, then a change to novel tasks may show additional performance advantages.

In the single-task condition of the running-memory task, response time improved with practice (Figure 8). The session by training interaction demonstrated a substantial initial VP training advantage in session nine, but by session ten, FP subjects performed at comparable levels. This suggests that VP training was immediately beneficial to subjects learning a novel task, but training benefits decreased as subjects practiced the tasks.

In Brickner and Gopher's (1981) study, subjects in equal priority training (equivalent to FP training in the present study) performed more poorly than subjects in the variable priority training in the dual-task conditions in the transfer tasks. These differences did not change with practice. In contrast to their results, VP training had more temporary results in the present study. The VP advantage had almost disappeared by session ten. A plausible explanation may be that older subjects need more extensive VP training in order to show longer lasting results. A similar finding in both studies was that the transfer task effects found were apparent in the dual-task performance only. Single-task results showed equivalent performance for both training groups.

Single-task performance on the scheduling task demonstrated a trade-off in terms of speed and accuracy. Practice effects were evident in all response time measures. Although accuracy did not improve with practice, there was a significant difference in accuracy performance between the two training groups. The VP group was significantly more accurate than the FP training group, up to eighteen percent more accurate on some versions of the task (e.g. easy dual-task version of incorrectly assigned automatic boxes). On correctly assigned automatic boxes, a training by level of difficulty interaction showed that the VP group outperformed the FP group on the easy version of the task, but the groups performed similarly on the two hardest levels of difficulty. This is also interesting to compare with results in the Brickner and Gopher (1981) study, because their findings suggest that VP training helped subjects protect single-task performance at other levels of difficulty. The older adults in this study, however, were not able show any real benefits with respect to training except at the easiest level.

In the dual-task condition of the scheduling task, difficulty effects were significant for all dependent measures. Also, training and difficulty interacted (Figure 9). The response time of the FP group remained stable across difficulty conditions, while those of the VP group increased with increases in difficulty. This finding runs contrary to results found in Brickner and Gopher (1981). At the very least, VP subjects were expected to perform as well as FP subjects. Accuracy results for this task were not significant, however they do suggest a speed/accuracy trade-off. At every level of difficulty in all three types of box assignment, VP accuracy was higher than FP accuracy by at least seven percent.

Running-memory task performance in the dual-task conditions showed practice effects in speed. A difficulty trade-off was present in accuracy. One possible reason why effects may not have been more prevalent in the scheduling/running-memory tasks is that subjects had opportunities to pre-determine the assignment of the next box before it appeared. By thus reducing the demands of performing the scheduling task, subjects had more resources to devote to performance on the running-memory task.

Instead of performing two tasks concurrently, subjects were effectively performing the two tasks serially.

In summary, the results of this study show several things. First, VP subjects showed consistent learning of the tasks during training, while FP subjects did not. Also, the VP training did not have a consistently beneficial effect on performance at various levels of difficulty in the VP trained tasks. Special consideration must be taken when an older population is trained using variable priority techniques. Online feedback as well as experimenter instruction is necessary to insure that subjects completely understand the variable priority manipulation. In some cases, even that will not be sufficient. Consideration will also have to be given to what levels of priority should be used. The results here implicate three levels of priority may be sufficient. Finally, subjects immediately benefitted from VP training in a novel task, however, subjects in FP training eventually reached the same performance level.

The continuation of this study will examine younger subjects' performance with variable priority training. Variable priority training effectiveness will be evaluated as well as a relative or absolute dual-task decrement with age.

In conclusion, a variable priority strategy can be useful for training or retraining older people if it is correctly administered. Potential implications of this research extend to many situations involving the learning of new, complex tasks. As the older population continues to increase in number, they also continue to learn new tasks. Some are learning new tasks as they stay in the job market longer, some as they enter the job market. Variable priority training can be utilized as a part of adapting to this trend.

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Tables

Table 1

Demographic Information of Training Groups

	Training	
Variable	Fixed[a]	Variable[b]
Age	66.3	68.9
Age Range	61-72	61-79
Years Education	16.5	16.3
# of Exercisers	8	6
Gender (Male/Female)*	1/11	5/3
K-Bit Composite Score	117.0	122.6
WAIS Digit Span	14.5	17.3
Self-Perceived Health		
Improving Health	5	4
Stable Health	7	3
Declining Health	0	1

[a]n = 12. [b]n = 8.

*p<.01.

Table 2

Session Itineraries

Session	Description
1	90 sec. demonstration letter-arithmetic task five 5 min blocks letter-arithmetic task 90 seconds demonstration gauge task five 5 min blocks gauge task
2	same as session #1
3	four 5 min. blocks letter-arithmetic task four 5 min. blocks gauge task six 5 min blocks dual-task
4	ten 5 min. blocks dual-task with online feedback two 5 min. blocks letter-arithmetic task two 5 min. blocks gauge task
5	same as session #4
6	same as session #4
7	four 5 min. blocks dual-task at each difficulty (no on-line feedback) one 5 min. block letter-arithmetic task one 5 min. block gauge task
8	same as session #7, except with opposite half of the alphabet
9	one 5 min. block running-memory task one 5 min. block scheduling task four 5 min. blocks dual-task at each difficulty (no on-line feedback)
10	same as session #9

Table 3

Mean Single Task Performance Data on Gauge Task in Task Familiarization Sessions

	Session	
Variable	2	3
Mean RT (msec)		
FP	3088	3062
VP	3322	3148
Median RT (msec)		
FP	2657	2702
VP	3060	2786
% Hits		
FP	49.6*	60.4
VP	65.7*	70.8
% Misses		
FP	22.8*	19.4
VP	20.3*	16.2
% False Alarms		
FP	27.6	20.2
VP	13.9	13.0

Note. FP = fixed priority training; VP = variable priority training.

*$p<.05$.

Table 4

Mean Single Task Performance Data on Letter Task in Task Familiarization Sessions

	Session	
Variable	2	3
Mean RT (msec)		
FP	7628	6758
VP	7690	6774
Median RT (msec)		
FP	6710	6017
VP	6667	6068
# Correct Responses		
FP	151.8	137.3
VP	189.9	135.8
% Correct		
FP	82.8	87.9
VP	86.1	87.1

Note. FP = fixed priority training; VP = variable priority training.

Table 5

Mean Dual Task Performance Data on Gauge Task in Session 3

	Training	
Variable	Fixed	Variable
Mean RT (msec)	3400	3616
Median RT (msec)	3146	3453
% Hits	46.2	44.0
% Misses	38.0	39.0
% False Alarms	15.8	17.1

Table 6

Mean Dual Task Performance Data on Letter Task in Session 3

	Training	
Variable	Fixed	Variable
Mean RT (msec)	17778	17556
Median RT (msec)	15263	15477
% Correct	88.0	85.9

Table 7

Mean Single Task Performance Data on Gauge Task in Training Sessions

	Session		
Variable	4	5	6
Mean RT (msec)			
FP	2814	2956	3027
VP	2938	2981	2848
Median RT (msec)			
FP	2495	2655	2696
VP	2523	2678	2458
% Hits			
FP	70.1	74.9	72.0
VP	71.2	73.9	74.8
% Misses			
FP	13.7	12.1	14.0
VP	13.9	10.8	11.5
% False Alarms			
FP	16.3	12.9	14.0
VP	14.8	15.3	13.7

Note. FP = Fixed priority training; VP = variable priority training.

Table 8

Mean Single Task Performance Data on Letter Task in Training Sessions

	Session		
Variable	4	5	6
Mean RT (msec)			
FP	5620	5151	5605
VP	5854	5697	5170
Median RT (msec)			
FP	4880	4580	4953
VP	5268	5323	4816
% Correct			
FP	89.1	90.4	89.3
VP	91.0	90.9	91.9

Note. FP = fixed priority training; VP = variable priority training.

Table 9

Mean Dual Task Performance Data on Gauge Task in Training Sessions

	Session		
Variable	4	5	6
Mean RT (msec)			
FP	3197	3309	3276
VP	3754	3570	3461
Median RT (msec)			
FP	2838	2976	2988
VP	3683	3253	3205
% Hits			
FP	45.8	47.6	51.1
VP	42.3	49.3	48.0
% Misses			
FP	41.8	40.6	37.0
VP	46.4	43.9	41.0
% False Alarms			
FP	12.5	11.8	10.4
VP	11.3	6.9	11.0

Note. FP = fixed priority training; VP = variable priority training.

Table 10

Mean Dual Task Performance Data on Letter Task in Training Sessions

	Session		
Variable	4	5	6
Mean RT (msec)			
FP	13168	12083	13583
VP	14275	12851	10874
Median RT (msec)			
FP	11028	9339	10187
VP	11544	10368	9243
% Accuracy			
FP	85.8	86.1	90.1
VP	89.9	91.6	89.5

Note. FP = fixed priority training; VP = variable priority training.

Table 11

Mean Performance Data on Letter Task of Fixed Priority Training Group Only

	Session		
Variable	4	5	6
Mean RT (msec)	13276	12780	13507
Median RT (msec)	10656	9571	10103
% Accuracy	85.3	87.5	88.1
Average Score	67.7	66.5	64.2

Table 12

Mean Performance Data on Gauge Task of Fixed Priority Training Group Only

Variable	Session 4	Session 5	Session 6
Mean RT (msec)	3206	3288	3308
Median RT (msec)	2941	2971	3020
% Hit	44.4	47.7	49.4
% Misses	42.2	42.3	39.3
% False Alarm	13.4	10.0	11.3
Average Score	79.0	76.2	75.9

Table 13

Mean Performance Data on Gauge Task of Variable Priority Training Group Only

	Session		
Variable	4	5	6
Mean RT (msec)	3589	3470	3474
Median RT (msec)	3416	3255	3286
% Hits	39.3	44.7	46.1
% Misses	49.7	46.3	44.4
Average Score	70.3	71.4	70.6

Table 14

Mean Performance Data on Letter Task of Variable Priority Training Group Only

	Session		
Variable	4	5	6
Mean RT (msec)	14012	13987	12572
Median RT (msec)	11830	11438	10052
% Accuracy	86.7	89.2	89.9
Average Score	62.1	60.8	63.4

Table 15

Mean Variable Priority Performance on Gauge Task

	Gauge Priority				
Variable	20	35	50	65	80
Mean RT	3559	3649	3595	3381	3372
Median RT	3388	3465	3381	3204	3159
% Hits	30.4	36.1	46.5	49.0	54.5
% Misses	63.0	53.6	43.8	39.3	34.3
Average Score	68.0	66.5	74.1	74.1	71.1

Table 16

Mean Variable Priority Performance on Letter Task

	Letter Priority				
Variable	20	35	50	65	80
Mean RT	8707	10437	12667	15651	20126
Median RT	6972	8585	10386	12930	16631
% Accuracy	88.1	89.7	90.3	87.0	87.8
Average Score	68.6	66.1	61.5	57.1	57.3

Table 17

Mean Single Task Performance on Gauge Task in Difficulty Transfer Session 7

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	3005	3065	3065
VP	2870	3063	3363
Median RT (msec)			
FP	2580	2777	2711
VP	2414	2861	3052
% Hits			
FP	68.0	74.6	69.7
VP	74.1	76.2	72.0
% Misses			
FP	15.0	11.7	16.7
VP	13.4	14.6	15.0
% False Alarms			
FP	17.0	13.7	13.6
VP	12.6	9.2	13.0

Note. FP = fixed priority training; VP = variable priority training.

Table 18

Mean Single Task Performance on Letter Task in Difficulty Transfer Session 7

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	4212	5722	7138
VP	4018	5535	8260
Median RT (msec)			
FP	3691	5059	6443
VP	3515	4981	7594
% Correct			
FP	93.5	84.6	81.2
VP	92.8	93.9	79.9

Note. FP = fixed priority training; VP = variable priority training.

Table 19

Mean Dual Task Performance Data on Gauge Task in Difficulty Transfer Session 7

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	3377	3278	3380
VP	3380	3461	3370
Median RT (msec)			
FP	3192	3016	3090
VP	3200	3157	3160
% Hits			
FP	37.6	48.6	48.7
VP	40.5	52.8	50.2
% Misses			
FP	46.6	41.4	40.7
VP	49.4	37.6	39.3
% False Alarms			
FP	15.8	10.0	10.5
VP	10.2	9.6	10.6

Note. FP = fixed priority training; VP = variable priority training.

Table 20

Mean Dual Task Performance Data on Letter Task in Difficulty Transfer Session 7

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	10740	10925	12360
VP	13931	14060	15887
Median RT (msec)			
FP	7837	8337	9108
VP	11748	12328	12791
% Hits			
FP	91.4	89.2	79.3
VP	91.6	89.9	78.1

Note. FP = fixed priority training; VP = variable priority training.

Table 21

Mean Single Task Performance on Gauge Task in Difficulty Transfer Session 8

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	3000	2978	3225
VP	3113	2837	3095
Median RT (msec)			
FP	2634	2676	2935
VP	2815	2894	2748
% Hits			
FP	72.7	75.9	70.6
VP	71.8	75.3	69.7
% Misses			
FP	14.0	12.4	15.4
VP	13.8	10.7	16.8
% False Alarms			
FP	13.3	11.7	14.0
VP	14.4	13.9	13.6

Note. FP = fixed priority training; VP = variable priority training.

Table 22

Mean Single Task Performance on Letter Task in Difficulty Transfer Session 8

Variable	Easy	Medium	Hard
	Difficulty		
Mean RT (msec)			
FP	4914	6900	6943
VP	3967	5200	7233
Median RT (msec)			
FP	4417	5895	6021
VP	3547	4635	6449
% Correct			
FP	93.7	83.8	77.7
VP	94.7	85.1	87.8

Note. FP = fixed priority training; VP = variable priority training.

Table 23

Mean Dual Task Performance Data on Gauge Task in Difficulty Transfer Session 8

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	3375	3350	3270
VP	3640	3453	3361
Median RT (msec)			
FP	3131	3103	2950
VP	3337	3186	3056
% Hits			
FP	42.8	46.6	51.4
VP	41.4	55.4	53.6
% Misses			
FP	43.8	39.3	38.4
VP	49.2	35.9	36.6
% False Alarms			
FP	13.4	14.1	10.2
VP	9.4	8.7	9.8

Note. FP = fixed priority training; VP = variable priority training.

Table 24

Mean Dual Task Performance Data on Letter Task in Difficulty Transfer Session 8

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	13644	13414	15095
VP	15331	13936	13916
Median RT (msec)			
FP	9955	10690	10947
VP	13758	12408	13046
% Hits			
FP	91.2	85.8	76.7
VP	89.9	87.9	78.8

Note. FP = fixed priority training; VP = variable priority training.

Table 25

Mean Single Task Performance Data on Running Memory Task in New Task Transfer Sessions

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	2974	3252	3455
VP	2645	2691	2836
Median RT (msec)			
FP	2806	3037	3064
VP	2540	2548	2599
% Accuracy			
FP	80.1	77.1	69.4
VP	82.2	77.5	74.7

Note. FP = fixed priority training; VP = variable priority training.

Table 5

Mean Single Task Performance Data on Manual Assignment Trials of Scheduling Task

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	1922	2390	2269
VP	1804	2342	2361
Median RT (msec)			
FP	1732	2270	2161
VP	1636	2251	2126
% Accuracy			
FP	79.6	62.1	61.3
VP	87.0	71.6	72.2

Note. FP = fixed priority training; VP = variable priority training.

Table 27

Mean Single Task Performance Data on Correct Automatic Assignment Trials of Scheduling Task

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	1253	1529	1628
VP	1239	1476	1529
Median RT (msec)			
FP	1103	1399	1490
VP	1146	1344	1461
% Accuracy			
FP	80.1	69.1	71.5
VP	90.5	65.7	69.6

Note. FP = fixed priority training; VP = variable priority training.

Table 28

Mean Single Task Performance Data on Incorrect Automatic Assignment Trials of Scheduling Task

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	1211	1472	1532
VP	1162	1594	1483
Median RT (msec)			
FP	1107	1329	1446
VP	1071	1428	1377
% Accuracy			
FP	73.8	50.2	60.0
VP	89.5	62.4	62.4

Note. FP = fixed priority training; VP = variable priority training.

Table 29

Mean Dual Task Performance Data on Running Memory Task in New Task Transfer Sessions

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	3209	2959	3396
VP	3518	3977	3665
Median RT (msec)			
FP	2715	2686	3004
VP	3075	3390	3254
% Accuracy			
FP	74.4	70.8	64.4
VP	84.9	81.7	78.1

Note. FP = fixed priority training; VP = variable priority training.

Table 30

Mean Dual Task Performance Data on Manual Assignment Trials of Scheduling Task

Variable	Difficulty		
	Easy	Medium	Hard
Mean RT (msec)			
FP	2326	2407	2385
VP	2304	2719	2629
Median RT (msec)			
FP	2072	2228	2201
VP	2096	2538	2385
% Accuracy			
FP	73.0	61.0	61.5
VP	86.6	73.1	69.2

Note. FP = fixed priority training; VP = variable priority training.

Table 31

Mean Dual Task Performance Data on Correct Automatic Assignment Trials of Scheduling Task

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	1519	1663	1604
VP	1594	1773	1667
Median RT (msec)			
FP	1337	1447	1370
VP	1350	1546	1463
% Accuracy			
FP	77.6	69.4	68.0
VP	84.2	76.5	76.5

Note. FP = fixed priority training; VP = variable priority training.

Table 32

Mean Dual Task Performance Data on Incorrect Automatic Assignment Trials of Scheduling Task

	Difficulty		
Variable	Easy	Medium	Hard
Mean RT (msec)			
FP	1722	1810	1681
VP	1644	1852	1782
Median RT (msec)			
FP	1505	1620	1470
VP	1389	1667	1488
% Accuracy			
FP	63.4	52.6	53.3
VP	81.3	63.8	64.6

Note. FP = fixed priority training; VP = variable priority training.

Figures

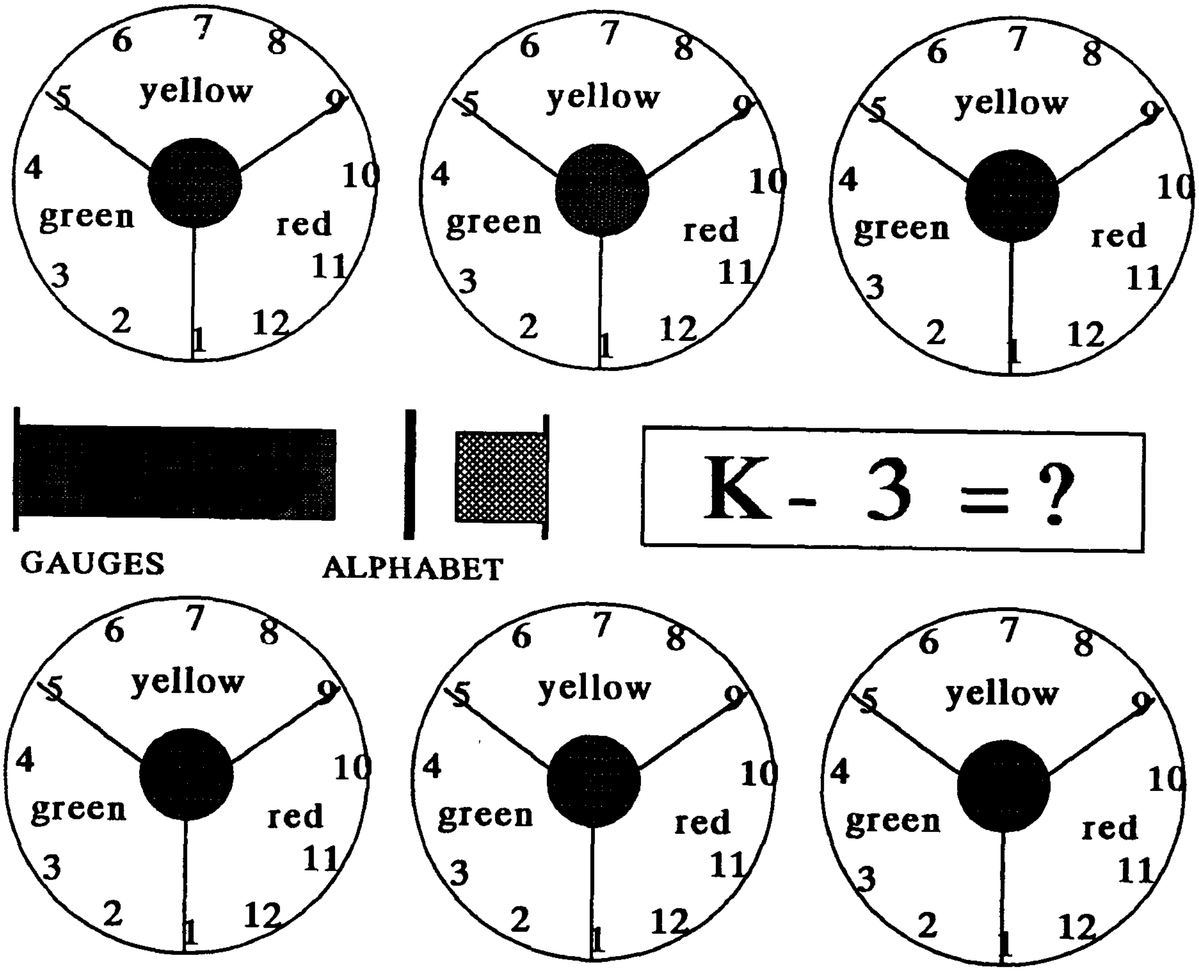


Figure 1. Dual-task display of gauge and letter-arithmetic tasks.

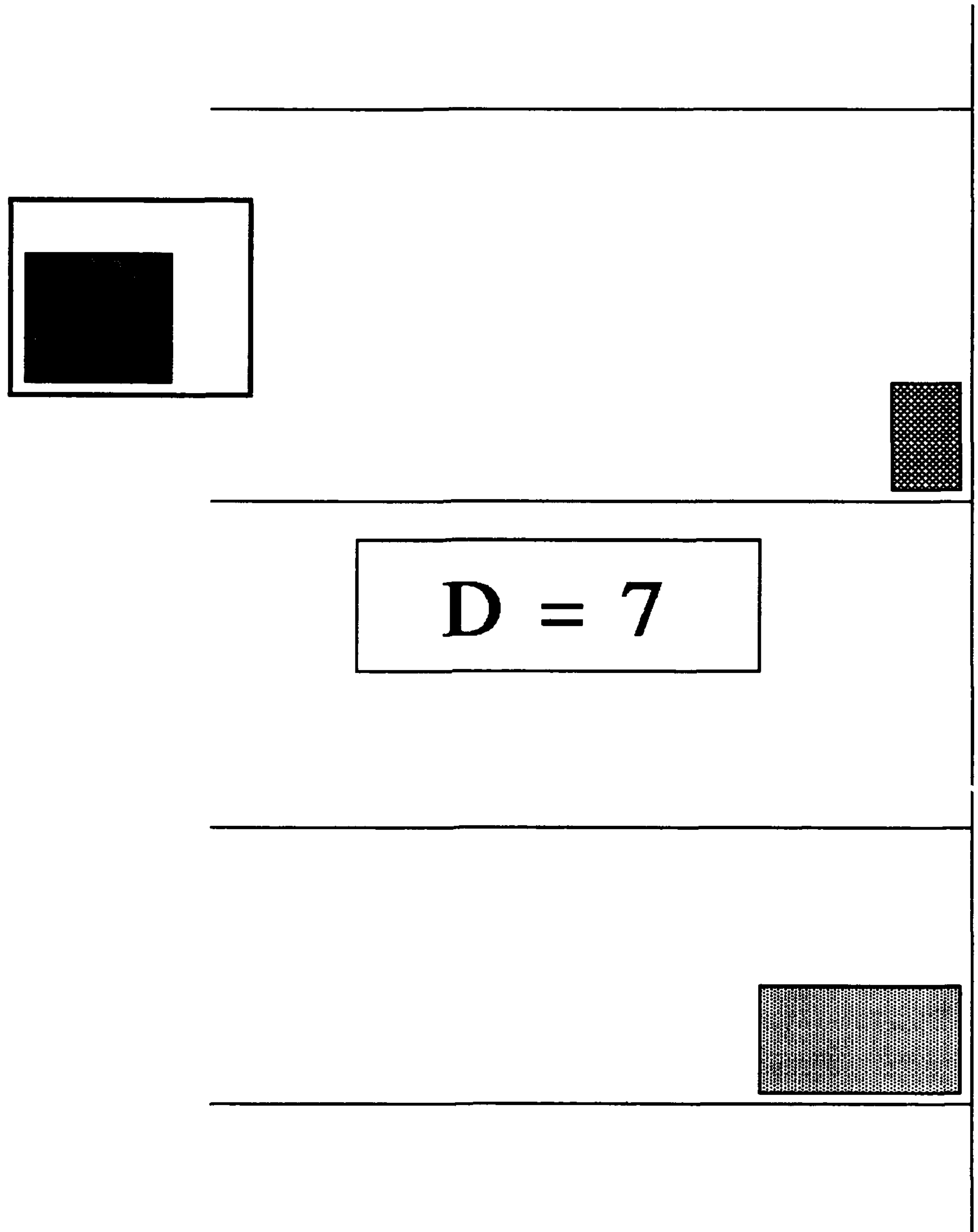


Figure 2. Dual-task display of scheduling and running-memory tasks.

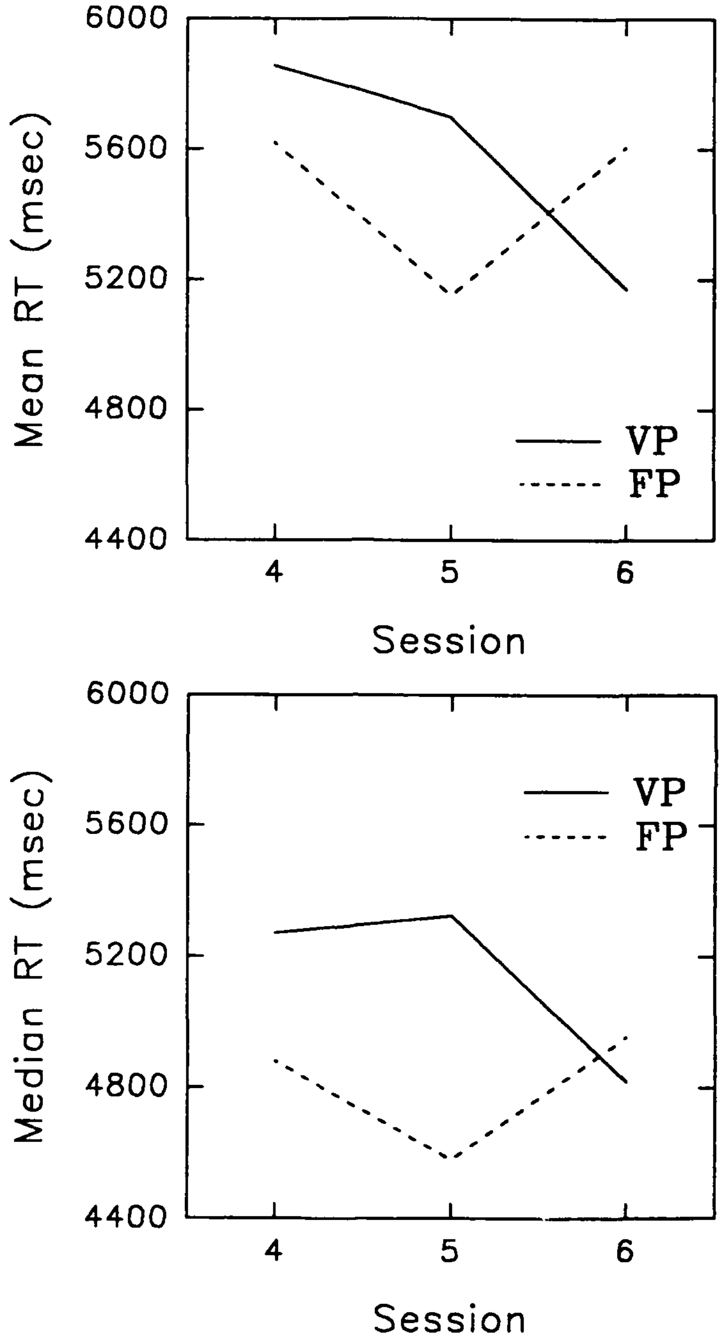
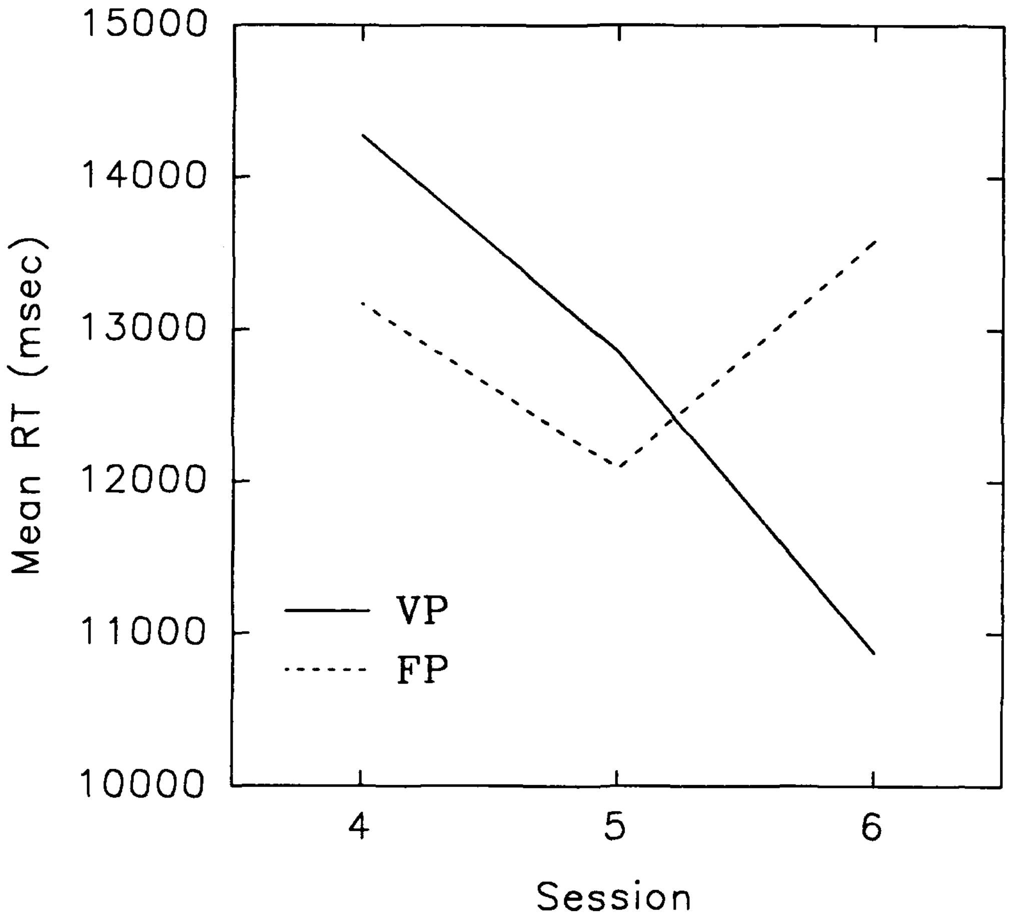
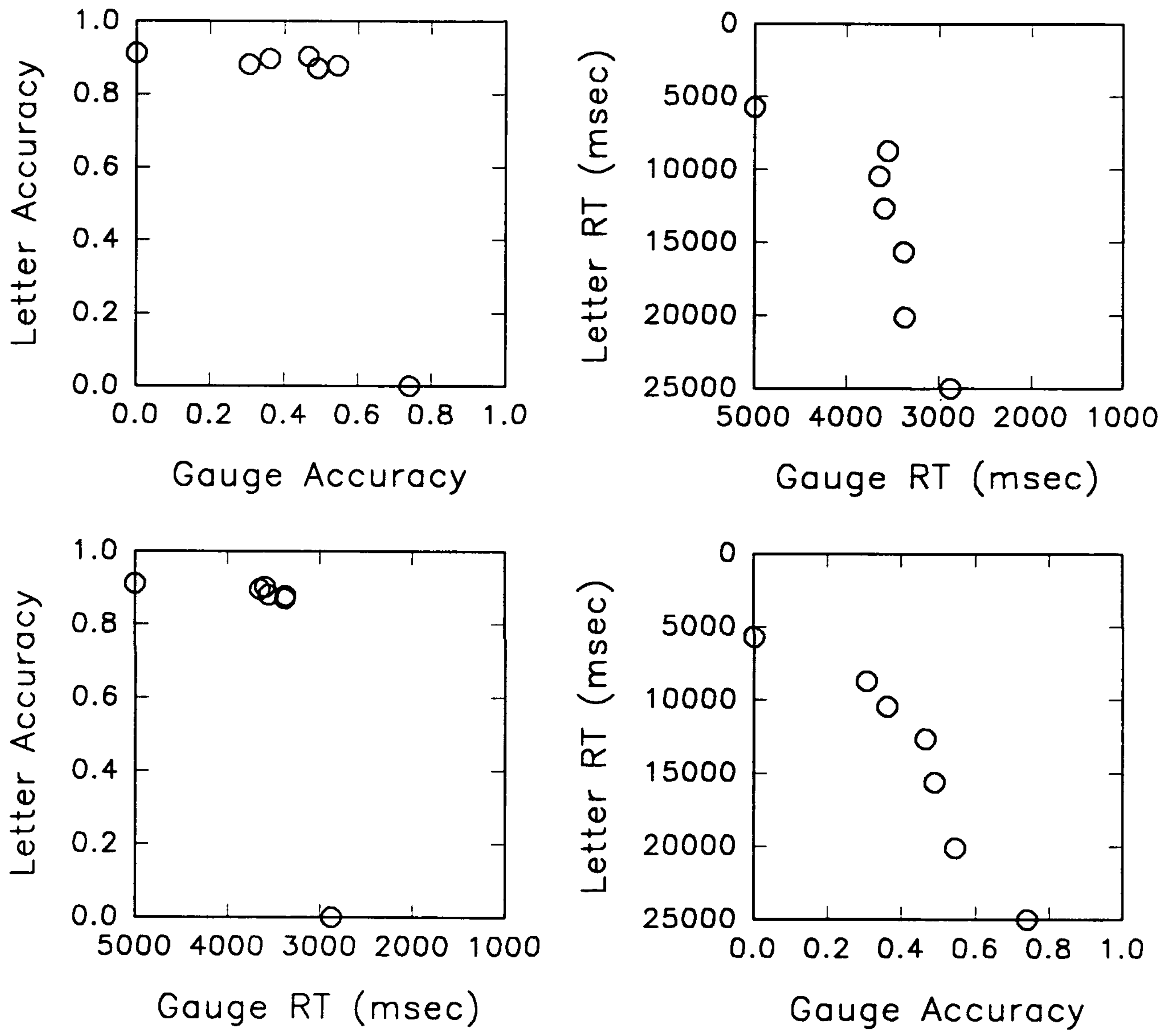


Figure 3. Single-task reaction time performance on letter-arithmetic task during training as a function of session and type of training type (VP = variable priority; FP = fixed priority).



<u>Figure 4</u>. Dual-task response time performance on letter-arithmetic task during training as a function of session and training type (VP = variable priority; FP = fixed priority).



<u>Figure 5</u>. Performance Operating Characteristics of variable priority subjects.

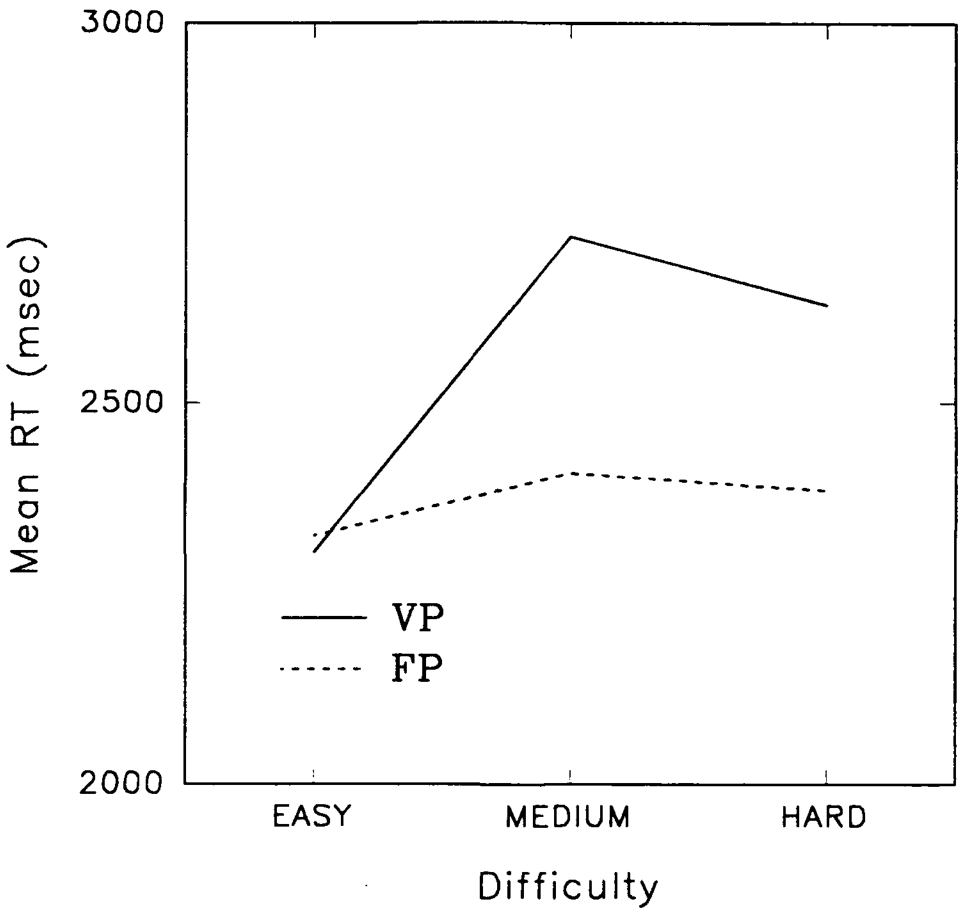
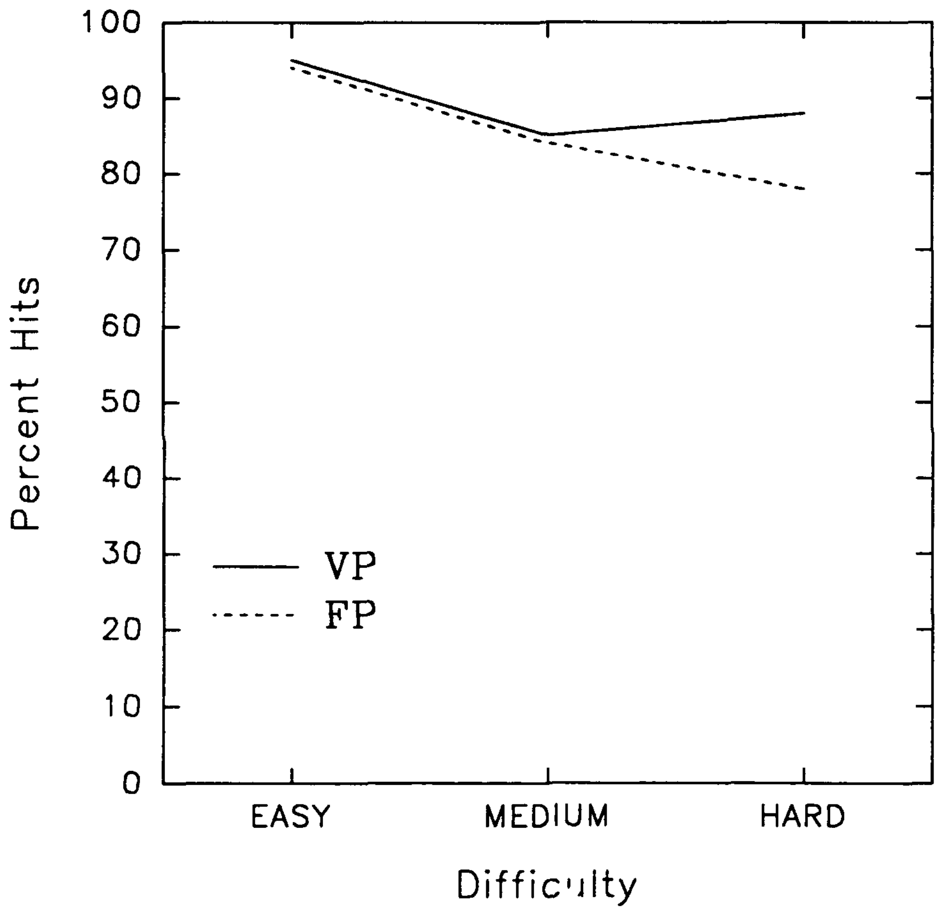
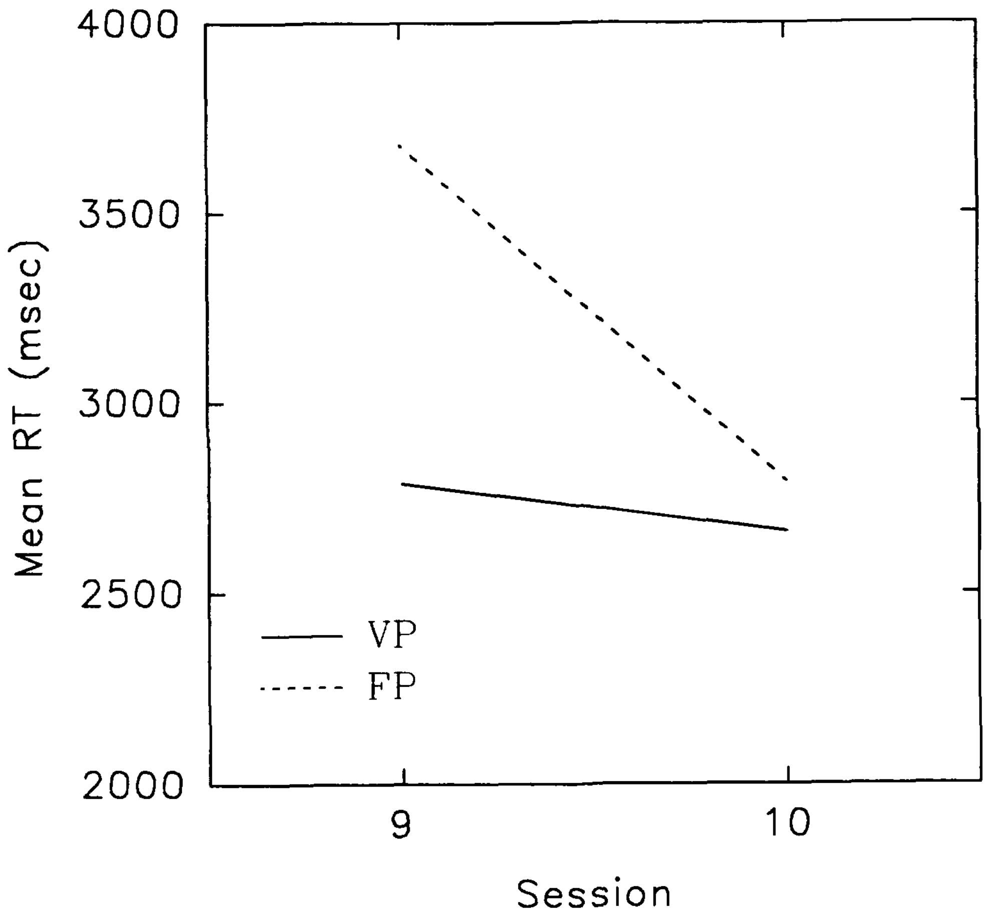


Figure 6. Single letter-arithmetic task response time performance in difficulty transfer session 8.



<u>Figure 7</u>. Accuracy performance on single letter-arithmetic task in session 8.



<u>Figure 8</u>. Single running-memory task reaction time performance as a function of session and training type (VP = variable priority; FP = fixed priority).

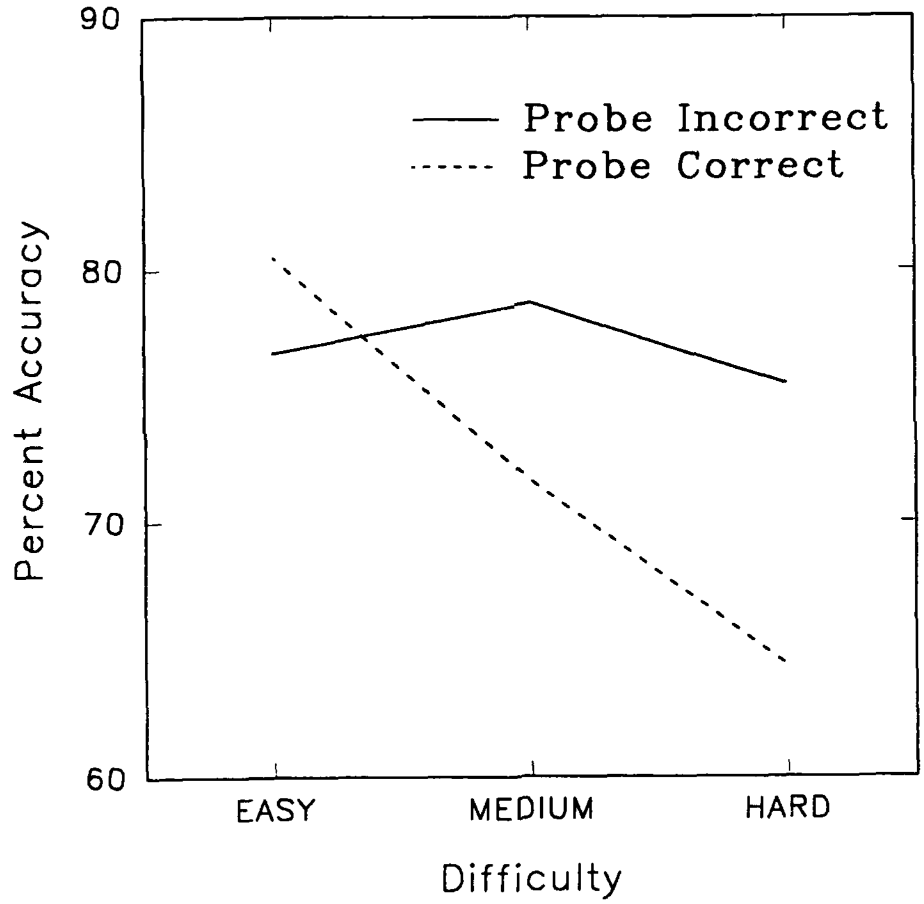


Figure 9. Dual-task running-memory task accuracy performance as a function of difficulty and probe type.

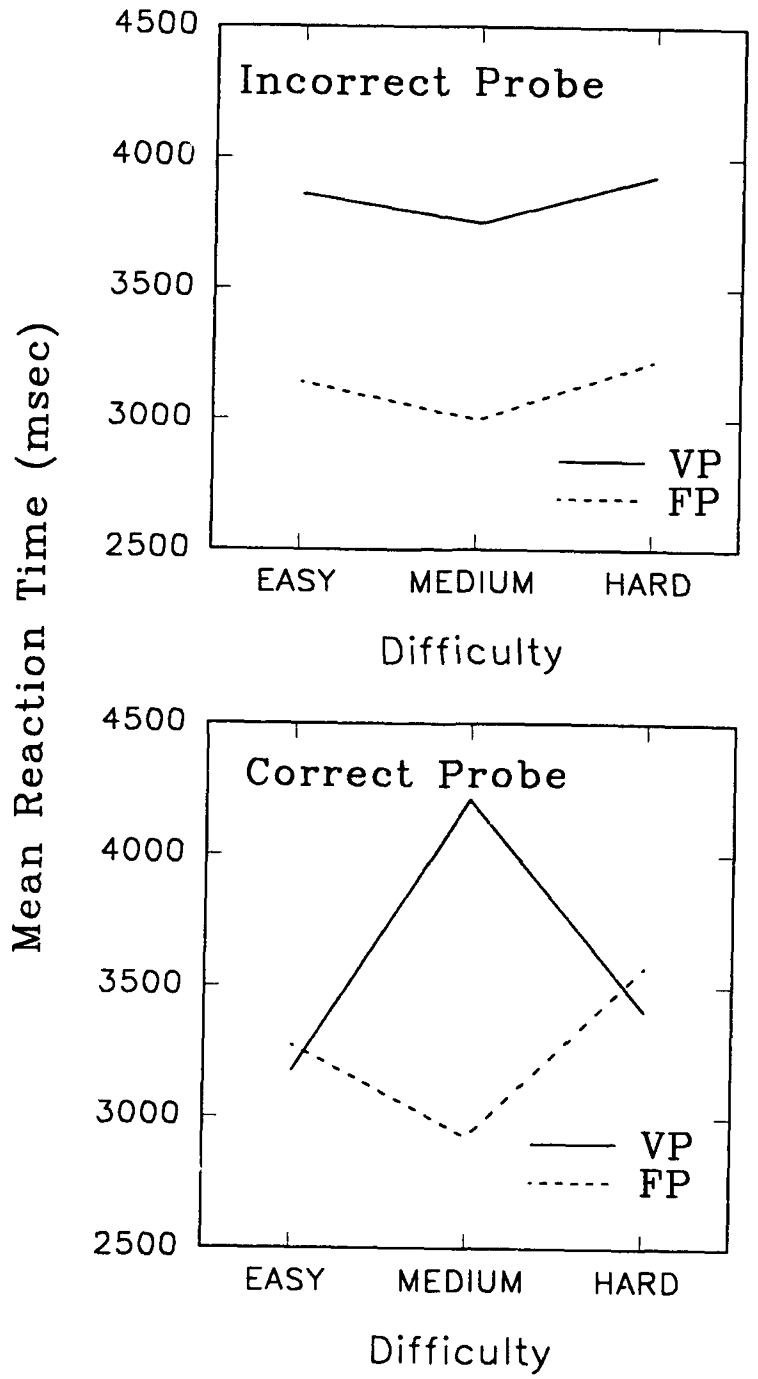
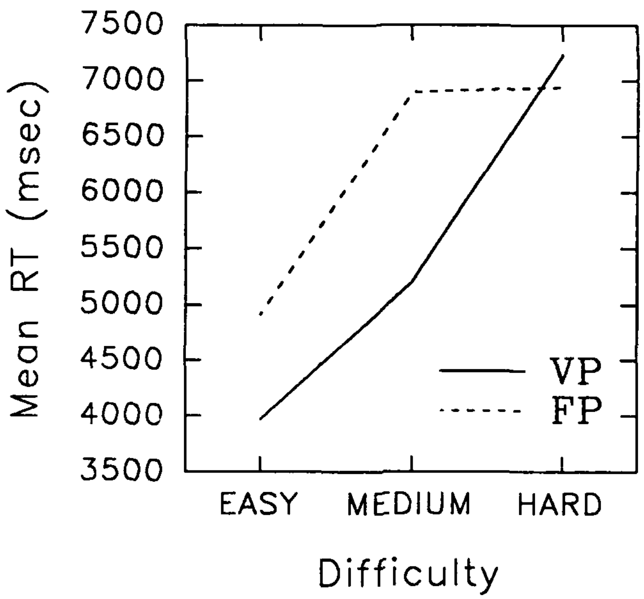


Figure 10. Dual-task running-memory reaction time performance as a function of probe type, difficulty and training.



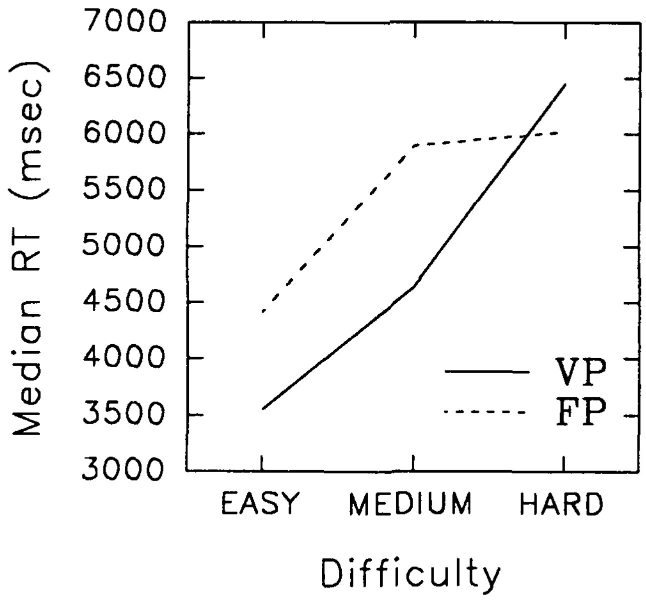


Figure 11. Dual-task scheduling reaction time performance of manual box assignment as a function of training and level of difficulty.

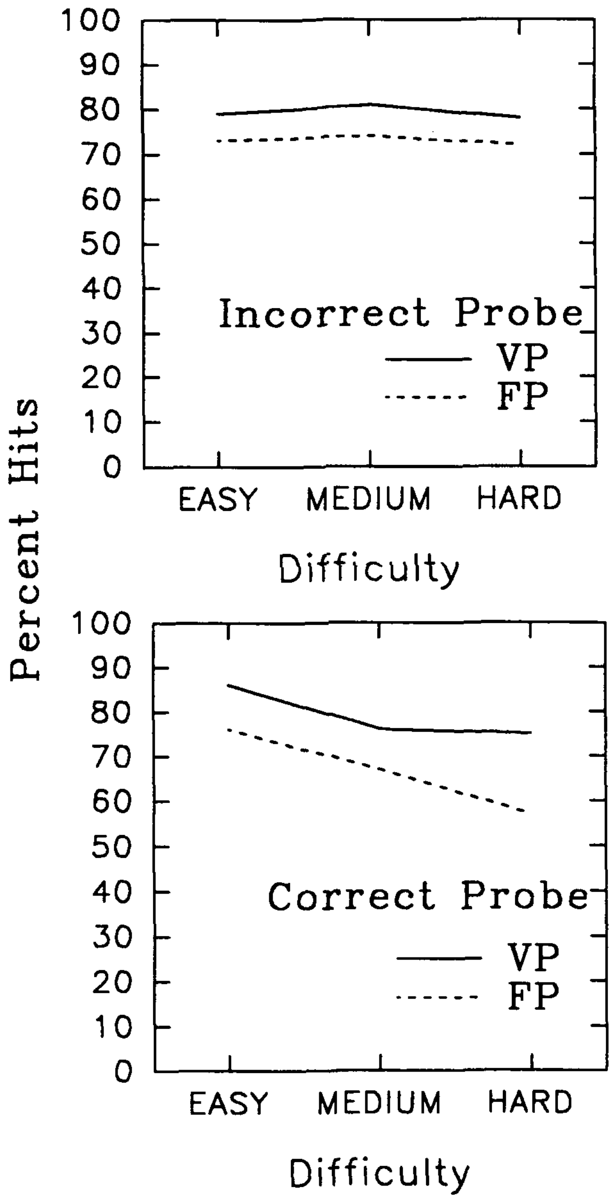


Figure 12. Dual-task running-memory accuracy performance as a function of probe type, difficulty and training.

Appendix A

INSTRUCTIONS FOR EASY GAUGE MONITORING TASK

In this task, you will be monitoring 6 gauges. The objective is to reset a gauge when the gauge marker is in the red. You will be timed on how quickly you reset a gauge, once it is in the red.

All 6 gauges are displayed at a time, however, you may only monitor one gauge's marker at a time. To monitor a gauge, use the following keys (found on the right side of the computer keyboard):

4	5	6
1	2	3

Once you've determined that a gauge needs to be reset, use these keys to reset the corresponding gauge:

Num lock	/	*
7	8	9

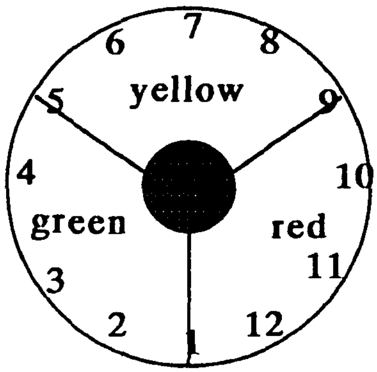
You will be penalized if the following occurs:

(1) if the marker is reset before it is in the red area or

(2) if the marker stays too long in the red area (longer than 5 seconds and the computer automatically resets the gauge.

*In this task, the speed of all markers in a row are correlated, meaning they move at the same rate, but they will not necessarily start at the same position.

*Remember to reset a gauge as soon as the marker is in the red! The task begins as soon as the gauges appear on the screen.



INSTRUCTIONS FOR MEDIUM GAUGE MONITORING TASK

In this task, you will be monitoring 6 gauges. The objective is to reset a gauge when the gauge marker is in the red. You will be timed on how quickly you reset a gauge, once it is in the red.

All 6 gauges are displayed at a time, however, you may <u>only monitor one</u> gauge's marker at a time. <u>To monitor a gauge</u>, use the following keys (found on the right side of the computer keyboard):

4	5	6
1	2	3

Once you've determined that a gauge needs to be reset, use these keys <u>to reset the corresponding gauge:</u>

Num lock	/	*
7	8	9

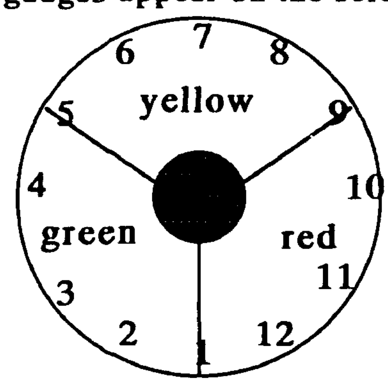
You will be penalized if the following occurs:

(1) if the marker is reset <u>before</u> it is in the red area, or

(2) if the marker stays too long in the red area (longer than 5 seconds), and the computer automatically resets the gauge.

*In this task, all column markers are correlated, meaning they move at the same rate, but they do not necessarily start at the same position. Also, the markers may slightly "jump" from time to time.

*Remember to reset a gauge <u>as soon as the marker is in the red!</u> The task begins as soon as the gauges appear on the screen.



INSTRUCTIONS FOR DIFFICULT GAUGE MONITORING TASK

In this task, you will be monitoring 6 gauges. The objective is to reset a gauge when the gauge marker is in the red. You will be timed on how quickly you reset a gauge, once it is in the red.

All 6 gauges are displayed at a time, however, you may <u>only monitor one</u> gauge's marker at a time. <u>To monitor a gauge</u>, use the following keys (found on the computer keyboard):

4	5	6
1	2	3

Once you've determined that a gauge needs to be reset, use these keys <u>to reset the corresponding gauge:</u>

Num lock	/	*
7	8	9

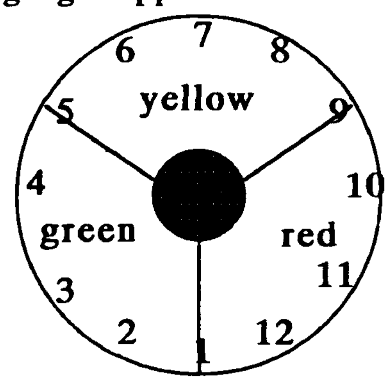
You will be penalized if the following occurs:

(1) if the marker is reset <u>before</u> it is in the red area, and

(2) if the marker stays too long in the red area (longer than 5 seconds), and the computer automatically resets the gauge.

*Each of the markers in this task moves independently of each other. In other words, they all have a different speed. In addition, the markers will "jump" fairly often.

*Remember to reset a gauge <u>as soon as the marker is in the red!</u> The task begins as soon as the gauges appear on the screen.



INSTRUCTIONS FOR EASY LETTER ARITHMETIC TASK

In this task, you will be adding numbers and letters. For example, in the equation:

C + 1 = ?

the correct response would be D.

In following equation:

K - 3 = ?

the correct response would be H.

The objective of this is to respond as quickly and as accurately as possible.

INSTRUCTIONS FOR MEDIUM LETTER ARITHMETIC TASK

In this task, you will be adding numbers and letters. For example, in the equation:

$$C + 1 = ?$$

the correct response would be D.

The first trial always appears in red. Assuming the red trial is correct, you will then have white trials. In all white trials, you must remember what key you pressed on the previous trial and compare it with the answer to the equation of this trial. You will type the letter that is (higher/lower) depending on direction of the white arrow.
For example,
if you had red trial:

$$\boxed{D + 2 = ?}$$

and you answered: F, you'd go on to the white trial.

the white trial might be:

$$\boxed{C - 1 = ?} \; \blacktriangle$$

Notice the arrow indicates the higher of the two answers. The first answer was F, the second, B, but the higher of the two is F. Therefore, F is the correct response.
The next trial might be:

$$\boxed{A + 2 = ?} \; \blacktriangledown$$

The correct answer in this case would be C, since the arrow indicates the lower of the two responses, C and F.
The next trial will also be white, so you should compare the answer C to the new answer. Be sure to check the arrow for the higher or lower response. If you answer incorrectly, you will start again with a red trial.

The objective of this is to respond as quickly and as accurately as possible.

INSTRUCTIONS FOR DIFFICULT LETTER ARITHMETIC TASK

In this task, you will be adding numbers and letters. For example, in the equation:

$$C + 1 = ?$$

the correct response would be D. The first trial always appears in red. Assuming the red trial is correct, you will then have white trials.

On the following trials, you must remember what should have been the answer to the previous trial and compare it with the answer to this trial. You do NOT compare the key you actually pressed on the previous trial, just compare the answer to the previous equation to the answer of the new equation. A correct response requires you to compare these answers, and you will type the answer that is (higher/lower) depending on direction of the white arrow. For example, if you had the first (red) trial:

$$\boxed{D + 2 = ?}$$

and you answered: F, you'd go on to the second (white) trial. The white trial might be:

$$\boxed{C - 1 = ?} \ \blacktriangle$$

Notice the arrow indicates the higher of the two answers. The first answer was F, the second, B, but the higher of the two is F. Therefore, F is the correct response.

The third trial might be:

$$\boxed{A + 2 = ?} \ \blacktriangledown$$

The answer to this equation is C, but we have to compare it to the answer to the previous equation, B. (Not what you actually pressed!) The arrow indicates the lower of the two responses, C and B. The correct response, therefore, would be B.

The next trial will also be white, so you should compare the answer C, (not what you pressed), to the new answer. Be sure to check the arrow for the higher or lower response. If you answer incorrectly, you will start again with a red trial.

The objective of this is to respond as quickly and as accurately as possible.

Appendix C

INSTRUCTIONS FOR EASY BOX SCHEDULING TASK

You're working for a box manufacturer and your job is to assign boxes to conveyor belts. You will put each box on the shortest line. In other words, the line with the shortest backup of boxes.

Use the following keys to assign boxes:

Num lock

7

4

1

There are red and blue boxes that will appear in a grey box in the top left corner of the screen. It is YOUR job to assign all the RED boxes to a line, the computer assigns all the blue boxes. Whenever the computer assigns a blue box, you must confirm that choice or change it to the correct line. Simply press the key corresponding to the line that the computer chose, if you feel the choice was correct. If you feel the computer should have chosen a different line, press that key instead. The computer makes a correct choice 60 percent of the time.

You will be timed on two things. First, how quickly you assign a red box once it appears is timed. Second, how quickly you verify (change) the computer's choice once the box is on a line is timed. Also, your accuracy in assigning boxes is scored.

You will be penalized for two things: (1) if the computer assigns a blue box to a line and you do not confirm (or change) the choice, and (2) if you do not assign a red box to a line within 7 seconds.

INSTRUCTIONS FOR MEDIUM BOX SCHEDULING TASK

You're working for a box manufacturer and your job is to assign boxes to conveyor belts. There are 3 different sizes of boxes to assign to these moving lines. Your job is to put each box on the line with the least amount of cumulative area (length x height). Big boxes are heavier and move slower than smaller ones. A good strategy is to look not only for the shortest line, but for the best combination of shortest and smallest boxes. Use the following keys to assign boxes:

Num lock

7

4

1

There are red and blue boxes that will appear in a grey box in the top left corner of the screen. You assign all the RED boxes to a line, the computer assigns all the blue boxes. Whenever the computer assigns a blue box, you must confirm that choice or change it to the correct line. Simply press the key corresponding to the line that the computer chose, if you feel the choice was correct. If you feel the computer should have chosen a different line, press that key instead.

You will be timed on two things. First, how quickly you assign a red box once it appears is timed. Second, how quickly you verify (change) the computer's choice once the box is on a line is timed. Also, your accuracy in assigning boxes is scored.

You will be penalized if: (1) the computer assigns a blue box to a line and you do not confirm (change) the choice, or (2) you fail to assign a red box to a line within 7 seconds.

INSTRUCTIONS FOR DIFFICULT BOX SCHEDULING TASK

You're working for a box manufacturer and your job is to assign boxes to conveyor belts. There are 5 different sizes of boxes to assign to these moving lines. Your job is to put each box on the line with the least amount of cumulative area (length x height). Big boxes are heavier and move slower than smaller ones. A good strategy is to look not only for the shortest line, but for the best combination of shortest and smallest boxes. Use the following keys to assign boxes:

$\boxed{\text{Num lock}}$

$\boxed{7}$

$\boxed{4}$

$\boxed{1}$

There are red and blue boxes that will appear in a grey box in the top left corner of the screen. You assign all the RED boxes to a line, the computer assigns all the blue boxes. Whenever the computer assigns a blue box, you must confirm that choice or change it to the correct line. Simply press the key corresponding to the line that the computer chose, if you feel the choice was correct. If you feel the computer should have chosen a different line, press that key instead.

You will be timed on two things. First, how quickly you assign a red box once it appears is timed. Second, how quickly you verify (change) the computer's choice once the box is on a line is timed. Also, your accuracy in assigning boxes is scored.

You will be penalized if: (1) the computer assigns a blue box to a line and you do not confirm (change) the choice, and (2) if you do not assign a red box to a line within 7 seconds.

INSTRUCTIONS FOR RUNNING MEMORY TASK

The computer will display, one letter-number pair at a time. To see the next pair, press the spacebar. A letter-number pair may look like the following:

$\boxed{A = 2}$

These pairs will appear in white. Your job is to remember the most recent value given to a letter. Then a red trial will ask you if this value for a letter is the most recent value for that letter. If the value given is correct, then use the correct keys to answer yes. The keys used for yes and no are ">" and "<" , but not necessarily in that order. Your experimenter will tell you which key corresponds to which answer.

A set of trials may go like this:

(white)	A = 2	(press the spacebar)
(white)	C = 7	(press the spacebar)
(white)	D = 4	(press the spacebar)
(white)	C = 6	(press the spacebar)
(white)	B = 1	(press the spacebar)
(white)	D = 2	(press the spacebar)
(red)	C = 7 ?	

The correct answer would be no (with either the "<" or ">" key). The most recent value was not 7, but 6.

And a new set of trials begins. However, you must remember the values from the previous set of trials, until they are replaced in the new set of trials. The numbers will be from 1 to 9. The letters vary as follows:

In the EASY version, letters will be A, B, or C.
In the MEDIUM version, letters will be A, B, C, or D.
In the DIFFICULT version, letters will be A, B, C, D, or E.